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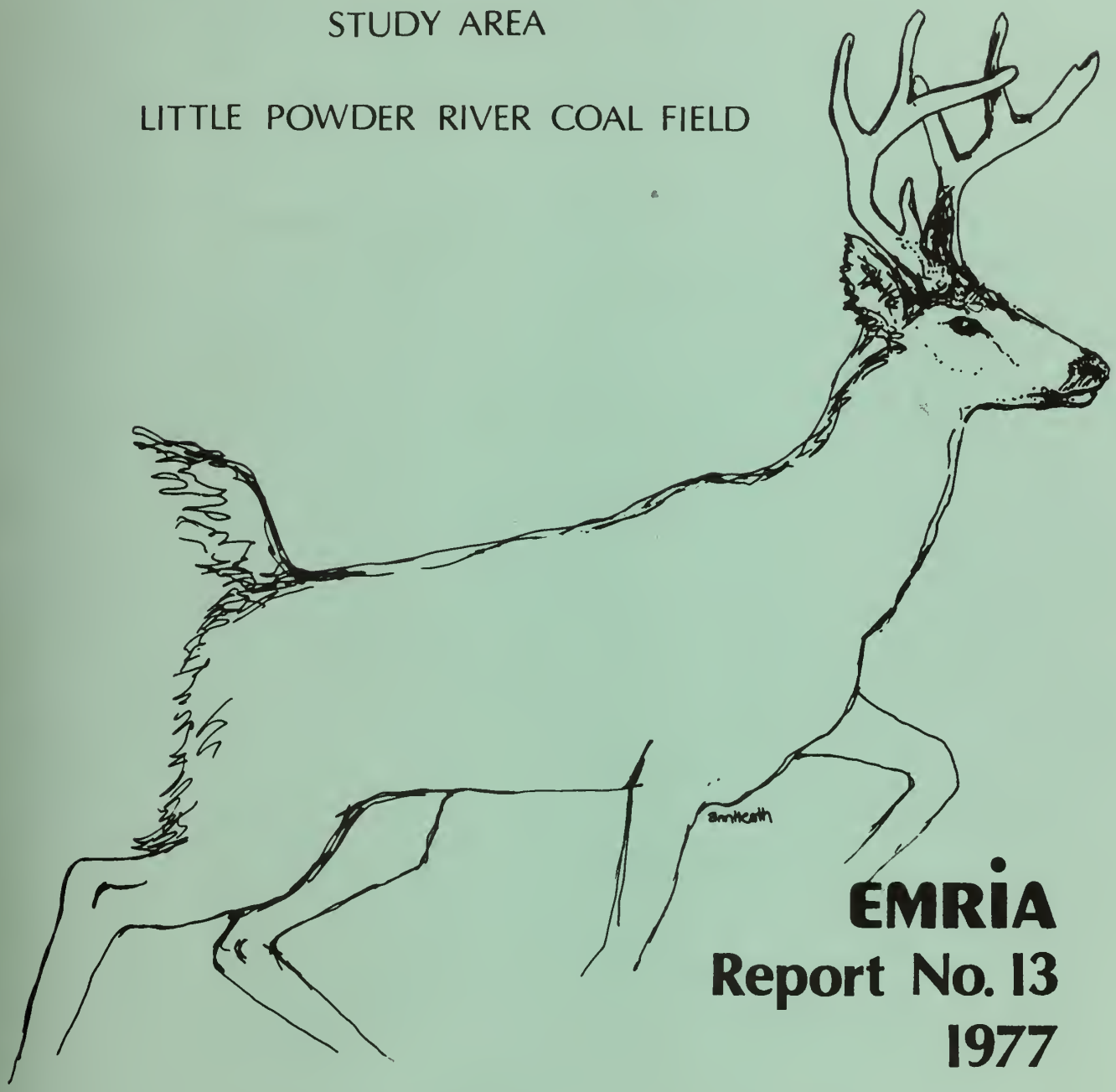
Resource and Potential Reclamation Evaluation

# WHITE TAIL BUTTE

STUDY AREA

LITTLE POWDER RIVER COAL FIELD



**EMRIA**
**Report No. 13**
**1977**

United States Department of the Interior
Bureau of Land Management
Water & Power Resources Service
Geological Survey

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# EMRIA
## (Energy Mineral Rehabilitation Inventory and Analysis)

EMRIA is a coordinated approach to the collection, analysis, and interpretation of overburden (soil and bedrock), hydrology, vegetation, and energy resource data. The main objective of the effort is to assure adequate baseline data for choosing reclamation goals and establishment of lease stipulations through site-specific preplanning for surface mining and reclamation.

These reports are prepared through the efforts of the Department of the Interior, principally by the Bureau of Land Management, Water and Power Resources Service, and Geological Survey. Assistance is also provided by other Federal and State agencies.

Reports under this effort are:

| EMRIA Report | Location |
|---|---|
| 1 | Otter Creek, Montana |
| 2 | Hanna Basin, Wyoming |
| 3 | Taylor Creek, Colorado |
| 4 | Alton, Utah |
| 5 | Bisti West, New Mexico |
| 6 | Foidel Creek, Colorado |
| 7 | Red Rim, Wyoming |
| 8 | Bear Creek, Montana |
| 9 | Horse Nose Butte, North Dakota |
| 10 | Beulah Trench, North Dakota |
| 11 | Pumpkin Creek, Montana |
| 12 | Hanging Woman, Montana |
| 13 | White Tail Butte, Wyoming |

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WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD
CAMPBELL COUNTY, WYOMING

CONTENTS

Page

Introduction---------- 1
Purpose---------- 1
Report Objectives---------- 1
Authority---------- 2
Responsibility---------- 2
Bureau of Land Management---------- 2
Water and Power Resources Service---------- 2
U.S. Geological Survey---------- 3
General Description---------- 3
Location---------- 3
Historical Summary---------- 4
Present Land Use---------- 4
Postmining Land Uses---------- 4
Surface Mining and Reclamation Regulations---------- 5
Federal---------- 5
State---------- 13
Objective of Reclamation---------- 25
Physical Profile---------- 26
Climate---------- 26
General---------- 26
Temperature---------- 26
Precipitation---------- 26
Other Climatic Factors---------- 27
Effect of Climate on Revegetation---------- 27
Physiography---------- 29
Geology---------- 30
Regional Geology---------- 30
Area Geology---------- 31
Investigations---------- 31
Stratigraphy---------- 32

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Page


Clinker---------- 33

Coalbeds---------- 34

Structure---------- 34

Paleontology---------- 35

Engineering Geology---------- 35

Slope Stability---------- 35

Overburden Expansion---------- 35

Instability of the Postmining Landscape------- 36

Weathering Tests---------- 37

Seismic---------- 38

Coal Resources---------- 39

Introduction---------- 39

Coal Resources of the White Tail Butte Study Area---------- 39

Coal Analysis---------- 40

Overburden - Soil and Bedrock---------- 42

Description of Principal Soil Bodies---------- 42

Land Suitability Survey---------- 44

Results of Land Suitability Survey---------- 45

Overburden Suitability---------- 46

Soil Mantle Suitability---------- 46

Bedrock Suitability---------- 47

Soil Inventory---------- 49

Description of Mapping Units---------- 50

Moisture Relations in Soils---------- 55

Study Sites---------- 56

Colluvial Soils---------- 57

Residual Soils---------- 58

Upland Alluvial Soils---------- 59

Valley Alluvium---------- 61

Greenhouse---------- 62

Introduction---------- 62

Methods---------- 62

Page


Fertilizer Treatments---------- 63
Seeding and Growth---------- 63
Harvesting---------- 63
Results---------- 64
Discussion---------- 64
Greenhouse Yields and Observations---------- 65
Additional Data---------- 66
Vegetation---------- 67
Hydrology---------- 69
Purpose and Scope---------- 69
Location---------- 69
Site-Numbering System---------- 69
Geologic Setting---------- 69
Fox Hills Sandstone---------- 70
Lance Formation---------- 70
Fort Union Formation---------- 70
Wasatch Formation---------- 71
Alluvium---------- 71
Hydrologic Classification of Land Types Using Rainfall Simulation---------- 71
Chemical Analyses---------- 72
Precipitation---------- 73
Hydrologic Class A---------- 73
Hydrologic Class B---------- 74
Hydrologic Class C---------- 74
Runoff, Infiltration Rates, and Sediment Concentration---------- 75
Surface Water Hydrology---------- 75
Description of Small Basins---------- 75
Data Collection---------- 76
Runoff---------- 76
Flow-Frequency Analysis---------- 77
Rainfall-Runoff Model---------- 77
Calibration---------- 79
Long-Term Weather Records---------- 80

Page


Comparison of Runoff from Basins---------- 81

Quality of Water---------- 82

Chemical Quality---------- 82

Impacts of Mining on Surface Water Hydrology-- 82

Sediment Yields---------- 83

Source-Area Sediment Yields---------- 84

Sediment Discharge from Drainage Basins------- 84

Computation of Annual Sediment Transport------ 85

Ground Water Hydrology---------- 86

Occurence and Availability---------- 86

Quality of Water---------- 86

Movement---------- 87

Impacts of Mining on Ground Water Hydrology--- 88

Availability of Water for Reclamation and Postreclamation Use---------- 89

Surface Water---------- 89

Ground Water---------- 89

Wildlife---------- 91

Cultural Resources---------- 92

Recreation and Visual Management---------- 93

Conclusions---------- 94

Climate---------- 94

Physiography---------- 94

Geology---------- 94

Coal Resources---------- 95

Overburden - Soil and Bedrock---------- 96

Moisture Relations in Soils---------- 96

Greenhouse---------- 97

Vegetation---------- 97

Hydrology---------- 97

Surface Water Hydrology---------- 97

Hydrologic Classification of Land Types Using Simulation Rainfall---------- 98

Sediment Yields---------- 98

Ground Water Hydrology---------- 99

Page

Wildlife---------- 99

Cultural Resources---------- 100

Recreation and Visual Management---------- 100

Recommendations for Reclamation---------- 101

Stability of the Postmining Landscape---------- 101

Restoration of Water Resources---------- 102

Surface Water---------- 102

Ground Water---------- 103

Erosion Control---------- 104

Revegatation---------- 105

Removal, Segregation, and Redistribution of Suitable Plant Growth Material---------- 105

Grading of Area Surfaces---------- 106

Selection of Adapted Plants---------- 106

Planting and Seedbed Preparation---------- 108

Application of Fertilizer and Soil Amendments--- 108

Management of the Revegetated Area---------- 108

Bibliography---------- 109

Appendix A - English to Metric Conversions

Appendix B - Geology

Appendix C - Coal Resources

Appendix D - Overburden - Soil and Bedrock

Appendix E - Greenhouse

Appendix F - Hydrology

## PLATES


| | Follows Page (Number) or located in Appendix (Letter) |
|---|---|
| Plate 1 - General Location Map | 4 |
| Plate 2 - Topography | 4 |
| Plate 3 - Mineral and Land Status Map | 4 |
| Plate 4 - Designation of Stream Order | 30 |
| Plate 5 - Generalized Regional Geologic Map | 30 |
| Plate 6 - Stratigraphic Column | 32 |
| Plate 7 - Geologic and Investigations Map | 32 |
| Plate 8 - Geologic Section W-X | 32 |
| Plate 9 - Geologic Section Y-Z | 32 |
| Plate 10-22 - Geologic Logs of Drill Holes DH76-101 through DH76-108 | B |
| Plate 23 - Overburden Thickness Map - Anderson Coalbed | 34 |
| Plate 24 - Overburden Thickness Map - Dietz Coalbed | 34 |
| Plate 25 - Overburden Thickness Map - Canyon Coalbed | 34 |
| Plate 26 - Detail Land Classification | 46 |
| Plate 27 - Detail Land Classification | 46 |
| Plate 28 - Detail Land Classification | 46 |
| Plate 29 - Detail Land Classification | 46 |
| Plate 30 - Detail Land Classification | 46 |
| Plate 31 - Surface Material Map | 46 |
| Plate 32 - Subhorizon Material Map | 46 |
| Plate 33 - Soils Map | D |
| Plate 34 - Vegetation Map of the White Tail Butte Area, Wyoming - 1976 | 68 |
| Plate 35 - Hydrologic Classification of the White Tail Butte, Wyoming EMRIA Study Area - 1976 | 72 |
| Plate 36 - Estimated Annual Source - Area Sediment Yields for the White Tail Butte Area, Wyoming - 1976 | 84 |
| Plate 37 - Channel Classification and Estimates of Sediment Discharge in the White Tail Butte Area, Wyoming - 1976 | 84 |

## FIGURES


| | Follows Page (Number) or located in Appendix (Letter) |
|---|---|
| Figure 1 - Comparison on Moist, Mineral-Matter-Free Basis of Heat Values and Proximate Analyses of Coal of Different Ranks (Modified from Trumbull, 1960)------ | C |
| Figure 2 - Relationship Used to Determine Void-Moisture Capacity (VMC) of Soils from Volume Weight (VW)---------- | 56 |
| Figure 3 - Calibration Relationships (McQueen and Miller, 1968) for Determining Moisture-Retention Force from Moisture Content of Standard Filter Papers at Equilibrium with Moisture in Samples of Soil, and Graph Illustrating Similar Relations in a Soil with One-Half the Adsorptive Surface---------- | 56 |
| Figure 4 - Relationships Between Size of Voids and Rate at which Water Infiltrates into Soils. Dashed Line Represents Confidence Limits Based on the Standard Error of Estimate Obtained for the Data---------- | 56 |
| Figure 5 - Locations of Sampling Sites for Defining Moisture Relations in Soils of the White Tail Butte Area, Wyoming - 1976---------- | 56 |
| Figure 6 - Schematic Diagram Showing the Influence of Orientation on Slope Gradients, and Relationship of Types of Surficial Materials to Topographic Positions---------- | 56 |
| Figure 7 - Photographic Aspect and Moisture-Retention Characteristics of Steep Upland Sites with Colluvial Soils---------- | 58 |
| Figure 8 - Photographic Aspect and Moisture-Retention Characteristics of Site with Shallow Residual Soils---------- | 58 |
| Figure 9 - Photographic Aspect and Moisture-Retention Characteristics of Sites with Deep Residual Soils---------- | 58 |
| Figure 10 - Photographic Aspect and Moisture-Retention Characteristics of Shrub-Dominated Alluvial Upland Sites---------- | 60 |
| Figure 11 - Photographic Aspect and Moisture-Retention Characteristics of Alluvial Soils in Low Areas------ | 60 |
| Figure 12 - Photographic Aspect and Moisture-Retention Characteristics of Sites on Valley-Floor Alluvium---------- | 60 |

FIGURES (Cont'd)


| | Follows Page (Number) or located in Appendix (Number) |
|---|---|
| Figure 13 - Yields of Western Wheatgrass on Overburden Samples from Coreholes DH76-101, DH76-102, DH76-103, and DH76-104, White Tail Butte Site in Wyoming | 64 |
| Figure 14 - Yields of Western Wheatgrass on Overburden Samples from Coreholes DH76-105, DH76-106, and DH76-107, White Tail Butte Site in Wyoming | 64 |
| Figure 15 - Yields of Western Wheatgrass on Soil Profile Samples from the White Tail Butte Site in Wyoming | 64 |
| Figure 16 - System of Numbering Wells and Test Holes | 70 |
| Figure 17 - Generalized Geologic Section of the Powder River Structural Basin, Northeastern Wyoming | 70 |
| Figure 18 - Stratigraphic Relation of Geologic Units Shown in Figure 17 | 70 |
| Figure 19 - Rainfall Simulation on the White Tail Butte Study Area. Top Photograph is Site 1, Middle is Site 2, and Bottom is Site 4 | 72 |
| Figure 20 - Recurrence of Maximum Yearly 24-Hour Rainfall (Apr.-Oct.) at Gillette, Wyoming | 74 |
| Figure 21 - Infiltration Curves for Site 1 | 76 |
| Figure 22 - Runoff and Sediment Concentration Curves for Site 1 | 76 |
| Figure 23 - Infiltration Curves for Site 2 | 76 |
| Figure 24 - Runoff and Sediment Concentration Curves for Site 2 | 76 |
| Figure 25 - Infiltration Curves for Site 3 | 76 |
| Figure 26 - Runoff and Sediment Concentration Curves for Site 3 | 76 |
| Figure 27 - Infiltration Curves for Site 4 | 76 |
| Figure 28 - Runoff and Sediment Concentration Curves for Site 4 | 76 |
| Figure 29 - Sketch of North Divide Draw near Recluse, Wyoming. Area of Exposed Clinker is Patterned | 76 |
| Figure 30 - Sketch of Elk Creek Tributary near Recluse, Wyoming. Area of Exposed Clinker is Patterned | 76 |

FIGURES (Cont'd)


| | Follows Page (Number) or located in Appendix (Letter) |
|---|---|
| Figure 31 - Instrumentation for Surface-Water Studies | 76 |
| Figure 32 - Maximum Runoff Events for Basins used in Runoff Investigations, June 12, 1977 | 78 |
| Figure 33 - Peak-Volume Relation for North Divide Draw near Recluse, Wyoming | 78 |
| Figure 34 - Peak-Volume Relation for Elk Creek Tributary near Recluse, Wyoming | 78 |
| Figure 35 - Log-Pearson Type III Annual Maximum Runoff-Recurrence Curves, North Divide Draw and Elk Creek Tributary near Recluse, Wyoming, Based on 73 Years of Simulated Data | 82 |
| Figure 36 - Log-Pearson Type III Peak Discharge-Recurrence Curves North Divide Draw and Elk Creek Tributary near Recluse, Wyoming, Based on 73 Years of Simulated Data | 82 |
| Figure 37 - Comparison of Peak-Flow Samples with Regional Confidence Limits | 82 |
| Figure 38 - Comparison of Runoff-Volume Samples with Regional Confidence Limits | 82 |
| Figure 39 - Change in PSP for Change in Total Infiltration | 84 |
| Figure 40 - Change in KSAT for Change in Total Infiltration | 84 |
| Figure 41 - Change in DRN for Change in Total Infiltration | 84 |
| Figure 42 - Change in RGF for Change in Total Infiltration | 84 |
| Figure 43 - Change in BMSM for Change in Total Infiltration | 84 |
| Figure 44 - Change in RR for Change in Total Infiltration | 84 |
| Figure 45 - Runoff-Frequency Curves Adjusted for Infiltration | 84 |
| Figure 46 - Peak-Discharge-Frequency Curves Adjusted for Infiltration | 84 |
| Figure 47 - Locations of Wells, Springs, and Test Holes Listed in Table 31, Appendix F | 86 |
| Figure 48 - Percentage of Cations and Anions in Ground Water, White Tail Butte | 88 |
| Figure 49 - Water Levels in Piezometers in the Canyon Coal | 88 |
| Figure 50 - Generalized Map of Water Levels in Wells Completed in the Fox Hills Sandstone, Lance Formation, and Lower Fort Union Formation in the Gillette Area | 88 |

FIGURES (Cont'd)

Follows Page (Number) or located in Appendix (Number)

Figure 51 - Water Levels in the Wyodak Coalbed in Central and Southern Campbell County, Wyoming---------- 88

Figure 52 - Relationship of the Potentiometric Surface in the Canyon Coal to the Coal---------- 88

## TABLES

On or Follows Page (Number) or located in Appendix (Letter)


Table 1 - Estimated Maximum Amounts of Rainfall in Powder River County, Montana, for Stated Periods of Duration and the Frequency that These Amounts Occur---------- 28

Table 2 - Elevation Changes Due to Bulking---------- 36

Table 3 - Classification of Coals by Rank---------- C

Table 4 - Estimated Identified Coal Resources of 3 Coalbeds within the EMRIA White Tail Butte Study Area, that is Shown on Plate 2---------- 40

Table 5 - Proximate and Ultimate Analyses, and Heat-of Combustion, Forms-of-Sulfur, Free-Swelling-Index and Ash-Fusion-Temperature Determinations for 3 Coalbeds from 4 Drill Holes, EMRIA White Tail Butte Study Area, Campbell County, Wyoming---------- 40

Table 6 - Major and Minor Oxide and Trace Element Composition of the Laboratory Ash of 3 Coalbeds from 4 Drill Holes, EMRIA White Tail Butte Study Area, Campbell County, Wyoming---------- 40

Table 7 - Major, Minor, and Trace Element Composition of 3 Coalbeds from 4 Drill Holes, EMRIA White Tail Butte Study Area, Campbell County, Wyoming----- 40

Table 8 - Comparison of the Average Content of Selected Trace Elements and Oxides in the Anderson, Dietz, and Canyon Coalbeds with Average Abundance in Coals of the Powder River Region-- 40

Table 9 - Elements that can affect Potential Utilization of Coals - Content in 63 Samples of Coal from White Tail Butte Area, in Parts per Million. (Reported on a Whole-Coal Basis)---------- 40

Table 10 - Point Site Profile of Shallow, Residual Soil on Ridges and Rolling Uplands---------- D

Tables (Cont'd)


On or Follows Page (Number) or located in Appendix (Letter)

Table 11 - Point Site Profile Of Moderately Deep, Residual Soil on Ridges and Rolling Uplands---------- D

Table 12 - Point Site Profile on Deep, Residual Soil on Ridges and Rolling Uplands---------- D

Table 13 - Point Site Profile on Residual Soil on Tabular Divide---------- D

Table 14 - Point Site Profile on Residual Soil on Semi-Badlands Terrain---------- D

Table 15 - Point Site Profile of Colluvial Soil on Footslope---------- D

Table 16 - Point Site Profile of Colluvial Soil on Footslope---------- D

Table 17 - Point Site Profile of Alluvial Soil on Fan------ D

Table 18 - Land Suitability Specifications - Surface Mine Reclamation - Suitability of Overburden for Revegetation of Surface-Mined Areas, BLM/BR Cooperative Program, EMRIA White Tail Butte Study Site---------- 44

Table 19 - Descriptions of Land Classes---------- 44

Table 20 - Suitability of Bedrock Material for Use as Plant Media for Revegetation---------- D

Table 21 - Interpretive Ratings for Soil Uses---------- D

Table 22 - Data for Defining Moisture Relations in Soils--- D

Table 23 - Plant Cover, in Percent, at Sites on Steep Uplands---------- 58

Table 24 - Plant Cover, in Percent, at Sites on Residual Soils---------- 59

Table 25 - Plant Cover, in Percent, on Shrub-Dominated Alluvial Upland Sites---------- 60

TABLES (Cont'd)


| | On or Follows Page (Number) or located in Appendix (Letter) |
|---|---|
| Table 26 - Plant Cover, in Percent, on Grass Dominated, Upland Alluvial Sites | 60 |
| Table 27 - Plant Cover, in Percent, on Valley Alluvium Sites | 61 |
| Table 28 - White Tail Butte Greenhouse Data | E |
| Table 29 - Yields of Western Wheatgrass as a Function of Weight of Soil per Pot | 66 |
| Table 30 - Percent Cover by Vegetation, Mulch, Bare Soil, and Rock as Determined by First-Contact Point-Quadrat Method Plus Weights of Vegetation and Mulch in Pounds per Acre | 68 |
| Table 31 - Records of Wells, Springs, and Test Holes | F |
| Table 32 - Data Obtained from Simulation Sites at White Tail Butte Study Area | 72 |
| Table 33 - Changes in Water Chemistry (+ or -) of Runoff Water as Compared to Applied Water | 72 |
| Table 34 - Physical Basin Characteristics | 76 |
| Table 35 - Model Parameters and Values | 80 |
| Table 36 - Comparison of Runoff Characteristics Obtained From the Basin Characteristics and this Study | 82 |
| Table 37 - Salinity Analysis of Water | F |
| Table 38 - Trace-Element Analysis of Water | F |

## PHOTOGRAPHS


Follows Page

Photograph 1 - Aerial View of the White Tail Butte Study Area---------- 4

Photograph 2 - Panoramic View of the North Divide Draw in Section 29, T. 56 N., R. 72 W.---------- 30

Photograph 3 - View Looking West into Study Area from Drill Hole 76-102---------- 30

Photograph 4 - View Looking North at Rounded Knobs of Anderson Clinker---------- 30

Photograph 5 - View Looking Southwest from Drill Hole 76-102 Toward White Tail Butte---------- 30

Photograph 6 - View Looking North from Drill Hole 76-103 Toward White Tail Butte---------- 30

Photograph 7 - Range in Western Wheatgrass Growth on Overburden Samples from the White Tail Butte Study Area---------- 64


## EXHIBITS


Appendix

Exhibit 1 - Screenable Soil Characterization as Related to Land Reclamation---------- D

Exhibit 2 - Laboratory Analyses and Procedures---------- D

Exhibit 3 - Supporting Data-Soil Profile Descriptions and Erosion Evaluations---------- D

Exhibit 4 - Glossary---------- D

# RESOURCE AND POTENTIAL RECLAMATION EVALUATION OF WHITE TAIL BUTTE STUDY AREA LITTLE POWDER RIVER COALFIELD CAMPBELL COUNTY, WYOMING

## INTRODUCTION

Recent energy shortages have forced our society to seek new domestic sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. It is the responsibility of the Department of the Interior and principally the Bureau of Land Management to assist in meeting these energy demands and at the same time, provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

## PURPOSE

The purpose of this report is to provide information for establishing reclamation objectives and lease requirements. Detailed data is given on geology, coal resources, overburden (soil and bedrock), greenhouse, vegetation, sedimentation and hydrology. Less detailed information is provided on climate, physiography, wildlife, cultural resources, recreation and visual management.

## REPORT OBJECTIVES

1. To analyze and quantify the environmental impacts from surface mining of coal.

2. To provide resource and impact information for leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

4. To provide resource and impact information to support state and local regional development and land use planning efforts.

5. To determine the present and potential capability of the soil and bedrock to support and maintain vegetation on known coal deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for exploration, mining and reclamation plans.

7. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study area.

## AUTHORITY

Federal Land Policy and Management Act of 1976 and Surface Mining Control and Reclamation Act of 1977.

## RESPONSIBILITY

### Bureau of Land Management

1. Selects reclamation study areas for coordinated investigation of vegetation, soil, geologic structure, surface water, and ground water.

2. Acts as Contracting Officer in the coordination, establishment and execution of work orders.

3. Procures easements and rights-of-way to conduct the studies.

4. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

5. Determines postmining land uses.

### Water and Power Resources Service 1/

1. Conducts a land classification for determining suitability of bedrock material for use in revegetation of shaped spoils.

2. Conducts drilling operations for the procurement of core samples for coal and soil analysis.

3. Characterizes and interprets suitability of overburden material as well as substrata immediately below the coal resources for purposes of revegetation.

4. Arranges for greenhouse studies for determining overburden materials potential for supporting vegetative growth.

5. Conducts mechanical weathering tests of core samples to determine stability of overburden materials.

6. Recommends to district office, Bureau of Land Management, suitable plant species for use in areas to be reclaimed.

7. Advises district office, Bureau of Land Management, on reclamation techniques.

8. Prepares geologic maps, logs and cross sections.

9. Advises the Bureau of Land Management on paleontological finds in the study area.

1/ Formerly the Bureau of Reclamation

## U.S. Geological Survey

1. Conducts vegetation and soil studies which result in vegetation maps and related soil characteristics.

2. Assesses reclamation potential based on water available from precipitation, the effects of surface mining on area hydrology, and the measures required to prevent adverse effects on surface and ground water of the area.

3. Prepares sediment yield maps.

4. Prepares erodibility maps.

5. Collects and interprets data to predict alternative solutions to ground water problems encountered during mining and reclamation.

6. Implements a monitoring system to define baseline conditions and document ground water changes in flow and quality caused by mining and reclamation.

7. Prepares ground water maps.

8. Tabulates coal resources estimates.

9. Prepares a table of analytical results of coal resources.

# GENERAL DESCRIPTION

## Location

The White Tail Butte Study Area is located in northeastern Wyoming, in Campbell County, approximately 35 miles north of Gillette (Plate 1 and 2 and Photograph 1). The site is comprised of about 2,450 acres of public land (Plate 3) described as follows:

Sixth Principal Meridian, Wyoming

T. 56 N., R. 72 W., Section 30 (within)
Section 31 (within)
Section 32 (all)

T. 56 N., R. 73 W., Section 24 (within)
Section 25 (within)

The site straddles the divide between White Tail and Elk Creeks, both tributaries of the Little Powder River. The site is drained to the north by two small ephemeral tributaries of Elk Creek. The watersheds drained by the two tributaries were selected for inclusion in the surface water studies associated with the White Tail Butte study.

## Historical Summary

The occupation of the northern Powder River Basin by Indians was one of a series of population movements. Rapidly increasing buffalo populations following the end of the last ice age drew tribes further out on the plains and into the Powder River Basin. During the period 1400-1600, the area including the White Tail Butte Study Area was occupied by Plains Apache. Later in this period, Crow and Shoshoni began encroachment as the Plains Apache moved southeast. During the period 1600-1700, it is hypothesized that the area was occupied by Shoshoni and Crow. The Crow were displaced to the west, in the period 1700-1800, with Arapaho and Teton Dakota emigrating into the Powder River Basin. By the 1850's, this portion of the Powder River Basin was occupied primarily by Teton Dakota (Reher, 1977).

The region was used by open range cattle operators after 1880. Homesteading in the area began in 1913, following the arrival of the Burlington Railroad. Some portions of the project area were claimed by homesteaders, but never patented.

The cultural resource inventory did not locate any significant historic values on the White Tail Butte Study Area. No cultural evidence of these historic users remains in the project area.

## Present Land Use

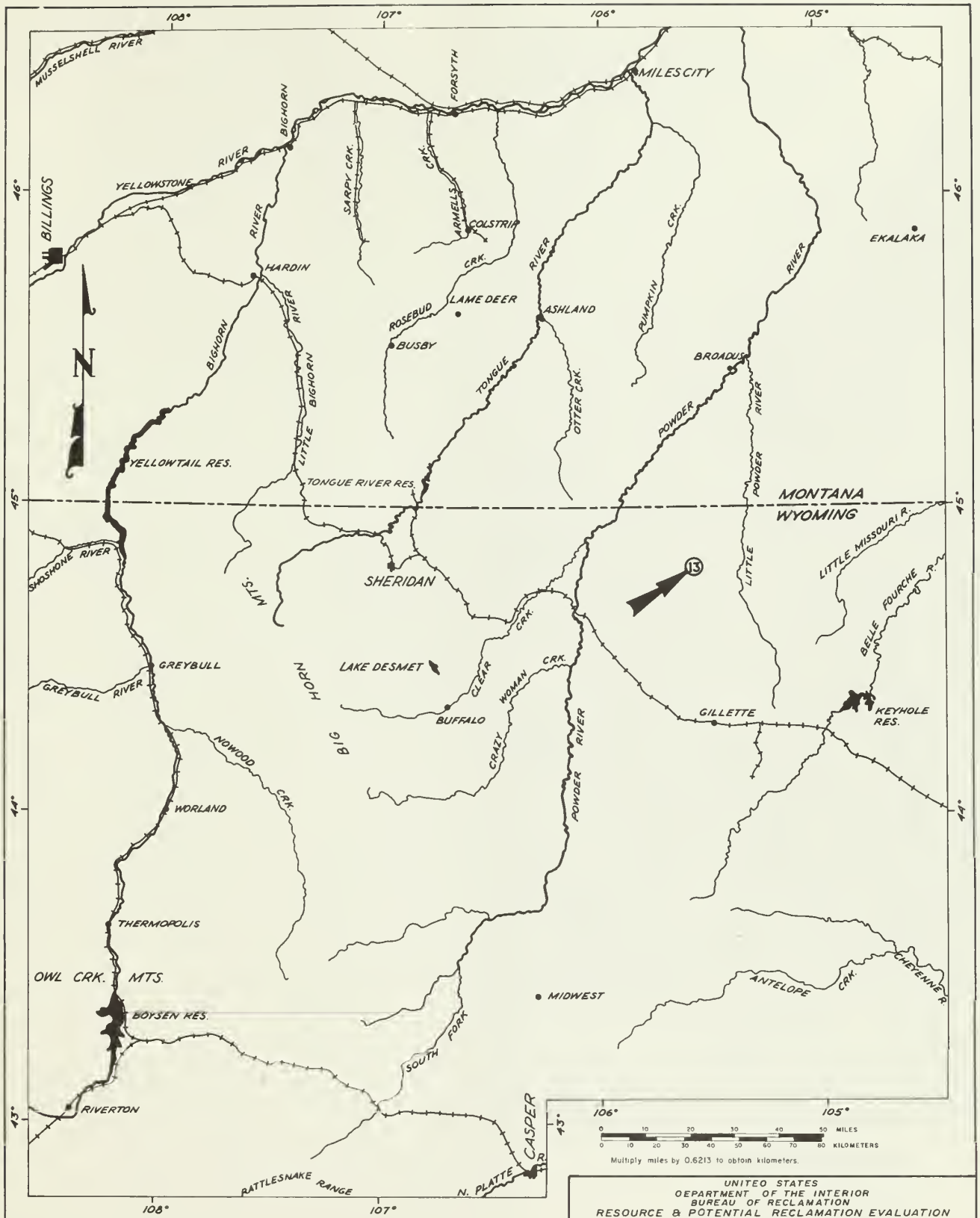
The area is not wilderness in character as defined in the Wilderness Act (P.L. 88-577; 78 Stat. 891). There are no proposals to manage the land as wilderness.

The area is 35 miles north of Gillette and, while there is legal access, no interest in it has been shown by local government due to its remoteness from Gillette. Public uses such as hunting or rockhounding will continue, but no intensive recreation or other public use is foreseen. There has been no interest shown in the land for residential, commercial or industrial occupancy. Any such uses would probably be made in association with mineral production activities.

The land is now used for livestock grazing, watershed protection, wildlife habitat and recreation. Intensive agricultural development is impractical because of limiting soil and climatic factors.

## Postmining Land Uses

The postmining land uses are expected to be similar to the present uses. Intensive agricultural development would require irrigation, but water of sufficient quantity and quality is not economically available.




UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

EMRIA STUDY AREA
MONTANA—WYOMING

# GENERAL LOCATION MAP

(13) WHITE TAIL BUTTE STUDY AREA-EMRIA NO. 13

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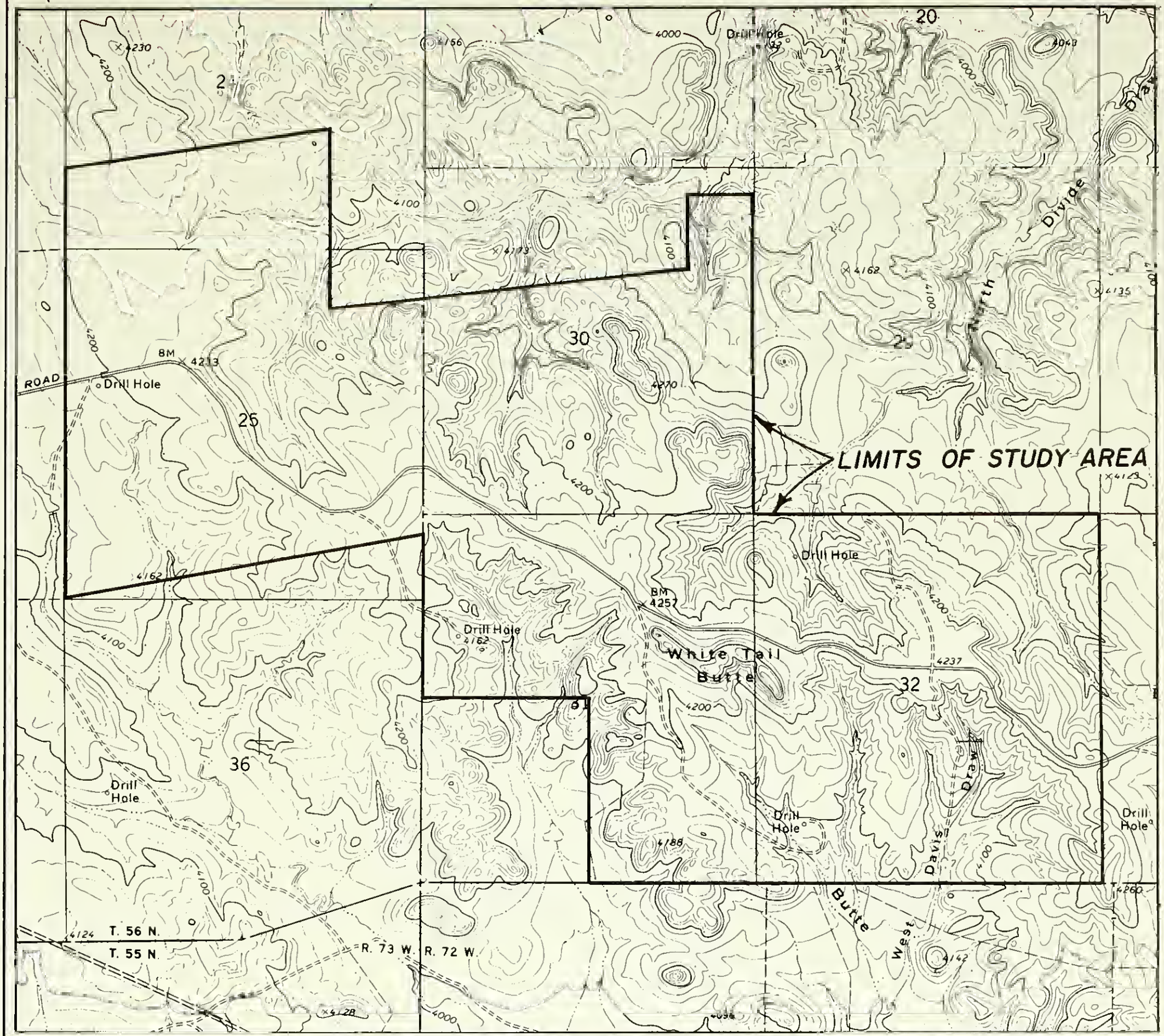
DRAWN G. TAUCHER RECOMMENDED _____
CHECKED _____ APPROVED _____

BILLINGS, MONTANA MARCH 1976 | 1305-600-35

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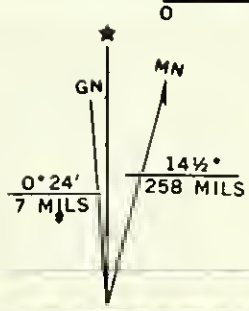
0 300 600 900 1200 1500 METERS

CONTOUR INTERVAL 20 FEET
Multiply feet by 0.3048 to obtain meters




UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

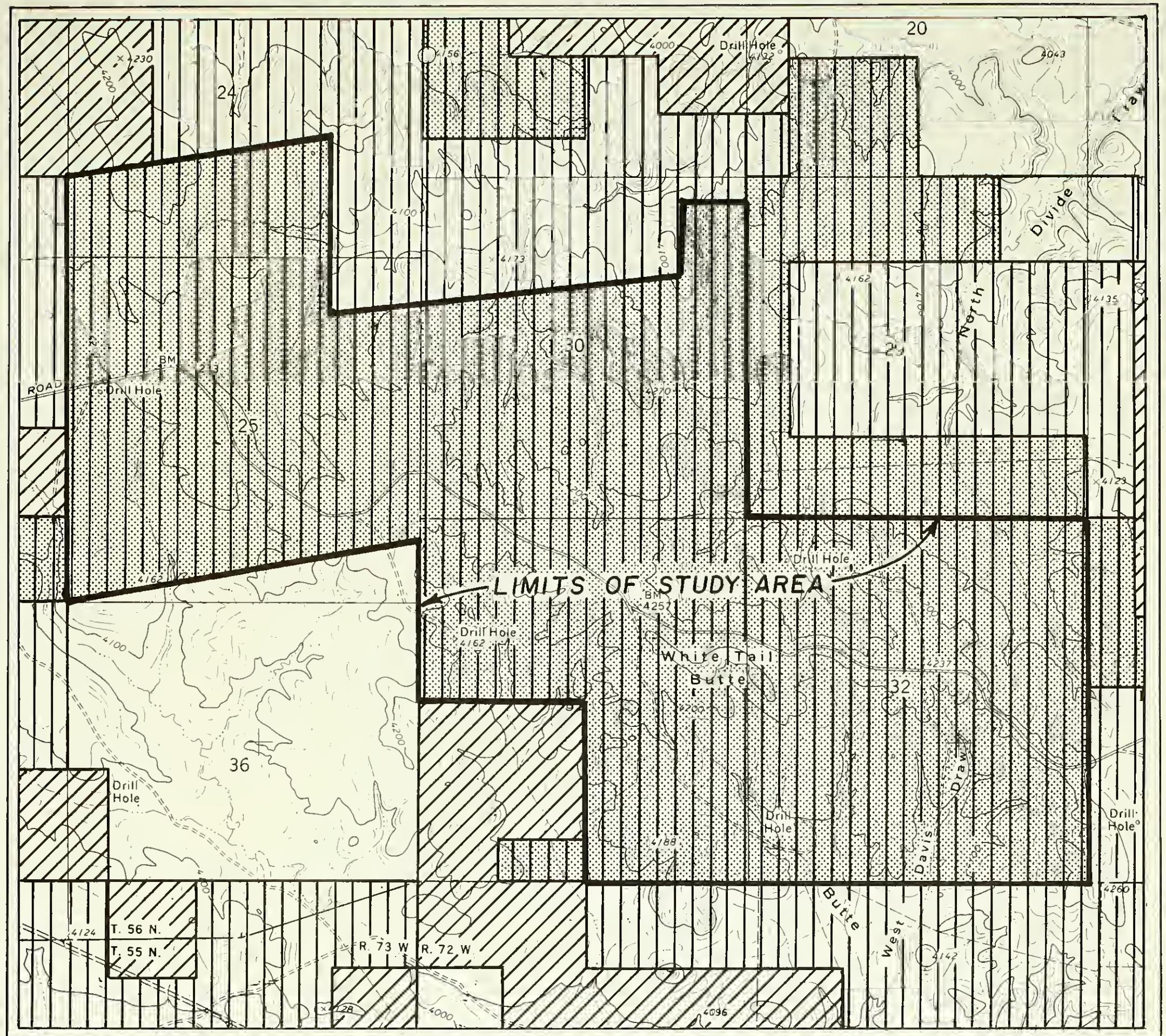
PORTION OF USGS WHITE TAIL BUTTE QUADRANGLE

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL
RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD
WYOMING

**TOPOGRAPHY**




0 1000 2000 3000 4000 5000 FEET

0 300 600 900 1200 1500 METERS

MINERALS OWNED BY FEDERAL GOVERNMENT

All Minerals

Coal Only

No Federal Minerals

LAND OWNED BY FEDERAL GOVERNMENT

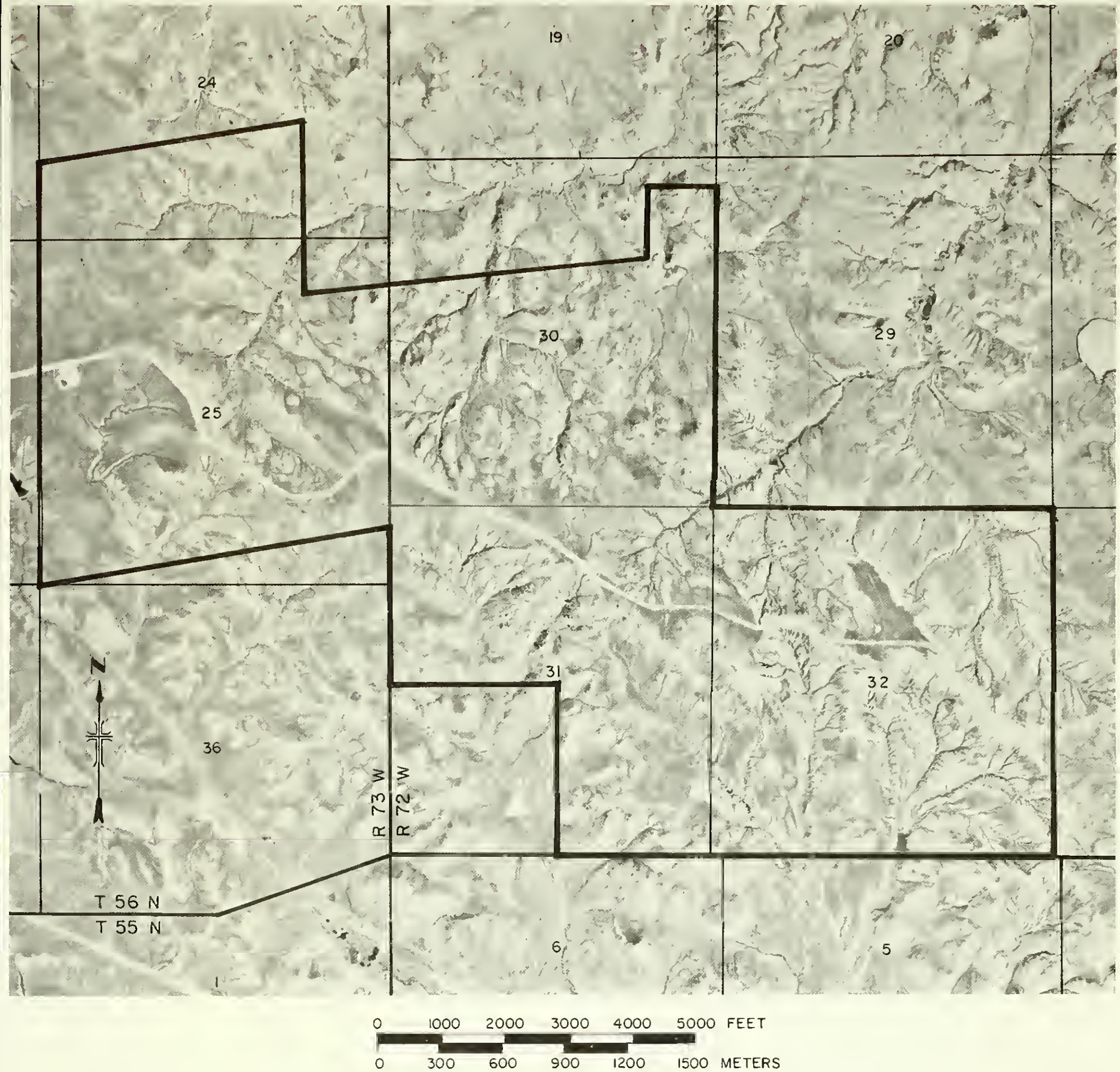
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL
RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD
WYOMING

MINERAL & LAND
STATUS MAP




Photograph 1 - WHITE TAIL BUTTE STUDY AREA - LITTLE POWDER RIVER COALFIELD, WYOMING - Aerial view of study area (outlined by heavy line)

## SURFACE MINING AND RECLAMATION REGULATIONS

Surface mine operators must comply with all established reclamation laws. Federal mining regulations are the minimum that are acceptable. They may be superseded by more stringent State regulations.

### FEDERAL

Federal coal mining regulations were published in the Federal Register, Volume 44, No. 50, March 13, 1979. Book 3, pages 15312-15463 states the rules and regulations of Chapter VII of 30 CFR, consisting of Parts 700-899, which establish the procedures through which the Secretary of the Interior will implement the Surface Mining Control and Reclamation Act of 1977.

Chapter VII is divided into 13 subchapters each having several parts dealing with various reclamation requirements. Subchapter K gives the standards for coal exploration and surface coal mining and reclamation operations during the permanent regulatory program. The regulations establish the minimum requirements for operations under State and Federal programs. Performance standards applicable to special mining situations such as anthracite mines, steep slope mining, alluvial valley floors, and prime farmlands are included.

Part 816 gives the regulations dealing specifically with surface mining activities. Selected passages from these regulations are given below, often in summarized form.

Part 816 Permanent Program Performance Standards--Surface Mining Activities.

Section 816.1 Scope.

This part sets forth the minimum environmental protection performance standards to be adopted and implemented under regulatory programs for surface mining activities.

Section 816.2 Objectives.

This part is intended to ensure that all surface mining activities are conducted in a manner which preserves and enhances environmental and other values in accordance with the Act.

Section 816.13 Casing and sealing of drilled holes: General requirements.

All exploratory holes, pits and openings shall be cased, sealed or managed to ensure safety and to prevent acid or toxic drainage from entering ground or surface water.

Section 816.21 Topsoil: General requirements.

(a). Before disturbance of an area, topsoil and subsoils to be saved shall be separately removed and segregated from other material.

(b). After removal, topsoil shall either be immediately redistributed or stockpiled pending redistribution.

Section 816.41 Hydrologic balance: General requirements.

(a). Surface mining activities shall be planned and conducted to minimize changes to the prevailing hydrologic balance in both the mine plan and adjacent areas, in order to prevent long-term adverse changes in that balance that could result from those activities.

(b). Changes in water quality and quantity, in the depth to ground water, and in the location of surface water drainage channels shall be minimized so that the approved postmining land use of the permit area is not adversely affected.

(c). In no case shall the Federal and State water quality statutes, regulations, standards, or effluent limitations be violated.

(d). Operations shall be conducted to minimize water pollution and where necessary, treatment methods shall be used to control water pollution.

Section 816.59 Coal recovery.

Surface mining activities shall be conducted so as to maximize the utilization and conservation of the coal, while utilizing the best appropriate technology currently available to maintain environmental integrity, so that reaffecting the land in the future through surface coal mining operations is minimized.

Section 816.71 Disposal of excess spoil: General requirements.

(a). Spoil not required to achieve the approximate original contour within the mined area shall be moved and placed in designated disposal areas within a permit area. The spoil shall be placed in a stable area suitable for reclamation and revegetation in controlled manner to ensure that leachate and surface runoff from the fill will not degrade surface or ground waters or exceed the effluent standards.

(b). The fill shall be designed using recognized professional standards, certified by a registered professional engineer, and approved by the regulatory authority.

(c). All vegetation and topsoil must be removed from the disposal area prior to placement of spoil. With approval, organic material may be included in the topsoil when it is replaced.

(d). Slope protection shall be provided for all spoil disposal areas. They shall be vegetated upon completion of construction.

(e). The disposal areas shall be located on the most stable and gently sloping areas available that are approved by the regulatory authority.

(f). The spoil shall be placed in compacted horizontal lifts to ensure stability and prevent mass movement, covered, and graded to allow surface and subsurface drainage to be compatible with the natural surroundings and ensure a long-term static safety factor of 1.5.

(g). The final configuration of the fill must be suitable for approved postmining land uses. No depressions or impoundments shall be allowed on the completed fill.

(h). Terraces may be used to control erosion and enhance stability, if approved.

(i). Where steep slopes (plus 36 percent) occur in the spoil disposal area, keyway cuts or rock toe buttresses shall be used to stabilize the fill.

(j). The fill shall be inspected for stability by a registered engineer or qualified professional specialist at least quarterly during critical construction periods. Certified reports must be filed within 2 weeks after each inspection and a copy shall be kept at the minesite.

(k). Coal processing wastes shall not be disposed of in head-of-hollow or valley fills, and may only be disposed of in other excess spoil fills if such waste is placed in accordance with specified regulations, demonstrated to be nontoxic and nonacid forming and consistent with the design stability of the fill.

(l). If the disposal area contains springs, natural or manmade watercourses, or wet-weather seeps, an underdrain system shall be constructed to prevent infiltration of the water into the spoil material.

(m). The foundation and abutments of the fill shall be stable under all conditions of construction and operation.

(n). Excess spoil may be returned to underground mine workings, but only in accordance with a disposal program approved by the regulatory authority and MSHA.

Section 816.79 Protection of underground mining.

(a). No surface coal mining activities shall be conducted closer than 500 feet to either an active or abandoned underground mine unless approved by the Mine Safety and Health Administration and the State, or the activities result in improved resource recovery, abatement of water pollution or elimination of public safety or health hazards.

(b). Surface mining activities shall be designed to protect disturbed surface areas, including spoil disposal sites, so as not to endanger any present or future operations of either surface or underground mines.

Section 816.81 Coal processing waste banks: General requirements.

(a). All coal processing waste shall be disposed of in approved disposal areas.

(b). Coal processing waste from activities outside a permit area may be disposed of in the permit area only if approved by the regulatory authority. The operator must show that disposal will not adversely affect water quality, water flow, vegetation, create health hazards, or cause instability in the disposal areas.

Section 816.86 Coal processing waste: Burning.

Coal processing waste fires may only be extinguished by the operator in accordance with plans approved by the regulatory authority and the Mine Safety and Health Administration.

Section 816.87 Coal processing waste: Burned waste utilization.

Before any burned coal processing waste, other materials, or refuse is removed from a disposal area, approval shall be obtained from the regulatory authority.

Section 816.89 Disposal of noncoal wastes.

Noncoal wastes shall be disposed of only in approved, specially designed and constructed disposal areas. At no time shall any solid waste material be deposited at refuse embankments or impoundment sites, nor shall any excavation for solid waste disposal be located within 8 feet of any coal outcrop or coal storage area.

816.91 Coal processing waste: Dams and embankments: General requirements.

Waste shall not be used in the construction of dams and embankments unless it has been demonstrated to the regulatory authority that the stability of such a structure conforms to established regulations. It shall also be demonstrated that the use of waste material shall not have a detrimental effect on downstream water quality or the environment due to acid seepage.

Section 816.95 Air resources protection.

The operator shall plan and employ fugitive dust control measures as an integral part of site preparation, coal mining, and reclamation operations. These controls must meet both Federal and State air quality standards.

Section 816.97 Protection of fish, wildlife, and related environmental values.

(a). Any operator shall, to the extent possible using the best technology currently available, minimize disturbances and adverse impacts of the mining activities on fish, wildlife, and related environmental values, and achieve enhancement of such resources where practicable.

(b). An operator shall promptly report to the regulatory authority the presence in the permit area of any critical habitat of a threatened or endangered species listed by the Secretary, any plant or animal listed as threatened or endangered by the State, or any bald or golden eagle, which was not previously reported.

(c). The operator shall ensure that all electric power lines and other transmission facilities are constructed according to regulations designed to protect eagles and other large birds.

Section 816.99 Slides and other damage.

(a). An undisturbed natural barrier shall be provided beginning at the elevation of the lowest coal seam to be mined and extending from the outslope for such distance as may be determined by the regulatory authority as is needed to assure stability. The barrier shall be retained in place to prevent slides and erosion.

(b). At any time a slide occurs which may have a potential adverse affect on public property, health, safety, or the environment, the operator shall notify the regulatory authority by the fastest available means and comply with any remedial measures required.

Section 816.100 Contemporaneous reclamation.

Reclamation efforts, including, but not limited to, backfilling, grading, topsoil replacement and revegetation, of all land that is disturbed by surface mining activities shall occur as contemporaneously as practicable with mining operations.

Section 816.101 Backfilling and grading: General requirements.

(a). Establishes the time limitations for following mining with backfilling and grading.

(b). Method of backfilling and grading.

(1). Unless specifically exempted, all disturbed areas shall be returned to their approximate original contour. All spoil shall be moved, backfilled, compacted, and graded to eliminate all highwalls, spoil piles, and depressions.

(2). Backfilled material shall be placed to minimize adverse effects on ground water, minimize off-site effects, and to support the approved postmining land use.

(3). The postmining graded slopes need not be of uniform slope.

(4). Cut-and-fill terraces may be used only in approved situations.

Section 816.103 Backfilling and grading: Covering coal and acid- and toxic-forming materials.

(a). Cover:

(1). A person who conducts surface mining activities shall cover, with a minimum of 4 feet of the best available nontoxic and noncombustible material, all exposed coal seams remaining after mining, and all acid-forming materials, combustible materials, or any other materials identified by the regulatory authority, as exposed, used, or produced during mining.

(2). If necessary, these materials shall be treated to neutralize toxicity, in order to prevent water pollution and sustained combustion and minimize adverse effects on plant growth and land uses.

(3). Where it is necessary to protect against upward migration of salts, a thicker cover may be necessary.

(4). Acid-forming or toxic-forming material shall not be buried or stored near a water course.

(b). Stabilization:

Backfilled materials shall be selectively moved and compacted, wherever necessary to prevent leaching of acid-forming and toxic-forming materials into surface or ground waters and wherever necessary to insure stability of the backfilled materials.

Section 816.106 Regrading or stabilizing rills and gullies.

When rills or gullies deeper than 9 inches form in areas that have been regraded and topsoiled, they shall be filled, graded, and the area reseeded or replanted.

Section 816.111 Revegetation: General requirements.

(a). Each person who conducts surface mining activities shall establish on all affected land a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of disturbed land or species that supports the approved postmining land use.

Section 816.112 Revegetation: Use of introduced species.

Introduced species may be substituted for native species only if approved by the regulatory authority under the following conditions:

(a). After appropriate field trials have shown that the introduced species are desirable and necessary to achieve the approved post-mining land use;

(b). The species are necessary to achieve a quick, temporary, and stabilizing cover;

(c). The species are compatible with native plant and animal species;

(d). The species are not poisonous or noxious.

Section 816.113 Revegetation: Timing.

Seeding and planting of disturbed areas shall be conducted during the first normal period for favorable planting conditions after final preparation. The normal period for favorable planting shall be that planting time generally accepted locally for the type of plant materials selected. A temporary cover of small grains, grasses, or legumes may be used until a permanent cover is established.

Section 816.115 Revegetation: Grazing.

When the approved postmining land use is range or pasture land, the reclaimed land shall be used for livestock grazing at a grazing capacity approved by the regulatory authority approximately equal to that for similar non-mined lands, for at least the 2 full years of liability.

Section 816.132 Cessation of operations: Permanent.

(a). Persons who cease surface mining activities permanently shall close or backfill or otherwise permanently reclaim all affected areas according to established regulations.

(b). All underground openings, equipment, structures, or other facilities not required for monitoring, unless approved by the regulatory authority as suitable for the postmining land use or environmental monitoring, shall be removed and the affected land reclaimed.

Section 816.133 Postmining land use.

(a). General.

All affected areas shall be restored in a timely manner --

(1). To conditions that are capable of supporting the uses which they were capable of supporting before any mining; or

(2). To higher or better uses achievable under established regulations.

(b). Determining pre-mining use of land. The pre-mining uses of land to which the postmining land use is compared shall be those uses which the land previously supported, if the land had not been previously mined and had been properly managed.

(c). Release of lands from the permit area. Prior to release of lands from the permit area they shall be restored, in a timely manner, either to conditions capable of supporting the uses they were capable of supporting before any mining or to conditions capable of supporting approved alternative land uses approved by the regulatory authority.

## STATE

General mining and reclamation guidelines are presented in the Wyoming Environmental Quality Act of 1973. Specific regulations governing reclamation procedures are stated in the Land Quality Rules and Regulations of the Wyoming Department of Environmental Quality (1978). These are interim regulations. Until permanent State regulations are approved by the Office of Surface Mining (USDI), the interim regulations will remain in effect.

The Wyoming Environmental Quality Act of 1973 pertains to all types of underground and surface mining. Some of the important features with respect to reclamation are (USDI; BLM 1975):

a. It repeals the 1969 Open Cut Land Reclamation Act.

b. It establishes a nine-man board to administer the act in place of the Land Commissioner. This board is appointed by the Governor.

c. It requires issuance of an operator's license and mining permits and sets provisions for denial of permits.

d. It requires advertisement of mining permit applications, and provides for filing objections to the applications, and for public hearings.

e. It requires land disturbed by mining to be returned to a use of equal or greater value than its prior use.

f. It requires a mining plan showing the nature and extent of the mineral resources, the land to be mined, and a description of mining operations with a time schedule.

g. It requires a reclamation plan prior to issuance of a mining permit. This plan must include:

   - Cost estimates for reclamation.

   - Maps showing extent of reclamation, which must be periodically updated.

   - Methods of regrading and recontouring the affected land.

   - Methods of stockpiling, preserving, and returning the topsoil.

   - Methods and plants used for revegetation.

h. It requires the prevention of water pollution from mine spoils.

i. It sets time limits on reclamation and can raise the surety on bonding requirements.

j. It requires the consent of the surface owner (if different from the mineral owner) to both the mining and reclamation plans.

Rules and Regulations of the Wyoming Department of Environmental Quality (1978) are presented in 13 chapters - each dealing with a specific aspect of land quality. Chapters II and III present regulations for mining and reclamation and water diversion and use. Excerpts from these chapters follow:

CHAPTER II

MINING AND RECLAMATION

Section 1. General requirements. All lands affected by any aspect of a mining operation after July 1, 1973, must be reclaimed to a use equal to or greater than the highest previous use of land prior to the land being affected by mining. An operator's intentions for accomplishing this goal must be described in detail in the operator's approved reclamation plan.

Section 2. Methods of mining - Reclamation required.

a. Soft rock surface mining.

(1). If the reclamation plan does not provide for a water impoundment, the final pit area shall be backfilled, graded and contoured to the extent necessary to return the land to the use specified in the approved plan. In preparation of slope specifications in the plan, the operator shall consider an average of the measured slopes in the immediate area of the proposed mine site. The maximum inclination of slopes in the reclaimed area shall not be greater than the average inclination of the natural slopes in the immediate mine area.

(2). If the reclamation plan provides for a water impoundment and this use has been approved, the exposed pit areas must be sloped, graded, and contoured so as to blend in with the topography of the surrounding terrain and provide for access and revegetation.

(3). For coal mining operations, surface and ground water shall not be discharged or diverted into underground mines.

Section 3. Surface preparation. Backfilling, grading, and contouring of affected land shall be accomplished by one or more of the following as detailed in the approved reclamation plan:

a. Reestablishment of the contour of the land in a manner consistent with the proposed future use of the land.

b. Reestablishment of adequate through drainage if such a provision is necessary to prevent erosion, pollution or the accumulation of stagnant water.

c. Contouring of affected land to blend in with the topography of the surrounding terrain unless so doing would create an erosion problem or a hazard to man or beast.

d. Creation of water impoundments for a use certified in an approved plan.

Section 4. Topsoil, subsoil, overburden, and refuse.

a. Topsoil

Topsoil, or an approved substitute, shall be evenly distributed on the surface of all lands affected during the course of the operation. Topsoil shall be so placed during the reclamation of all areas that are to be revegetated in accord with the approved reclamation plan.

(1). All topsoil or approved surface material shall be removed from all areas to be affected in the permit area prior to these areas being affected. The topsoil shall be segregated so as not to become mixed with subsoil and other overburden material, stockpiled in the most advantageous manner and saved for reclamation purposes.

(2). The topsoil or approved surface material shall be stockpiled in such a manner so as to minimize wind and water erosion. In order to accomplish this, the operator shall establish, through planting or other acceptable means, a quick growing cover of vegetation on the topsoil stockpiles. The topsoil shall also be protected from acid or toxic materials, and shall be preserved in a useable condition for sustaining vegetation when placed over affected land.

(3). Reclamation shall follow mining as soon as is feasible so as to minimize the amount of time topsoil must be stockpiled. If topsoil has been stored in a stockpile in excess of 1 year, the operator shall conduct soil analyses prior to use in order to determine its suitability for revegetation.

(4). Topsoil stockpiles shall be marked with a legible sign containing letters not less than 6 inches high on all approach roads to such stockpiles. Said signs shall contain the word "Topsoil" and shall be placed not more than 150 feet from any and all stockpiles of topsoil. Such signs must be in place at the time stockpiling is begun.

(5). The operator shall explain how the topsoil will be replaced on the affected land during reclamation, and shall indicate on his maps the locations and sizes of all proposed topsoil stockpiles. This explanation shall include a description of the thickness of topsoil to be placed over the affected land and procedures that will be followed to protect the topsoil from excessive compaction and wind and water erosion until vegetation has become adequately established.

(6). If abundant topsoil is present, and it is not all needed to accomplish the reclamation required in the approved reclamation plan, the administrator may approve of use of this topsoil by this or another operator in another area for reclamation purposes.

(7). Trees, large rocks and other waste material which may hinder redistribution of topsoil shall be separated from the topsoil before stockpiling.

(8). For surface coal mining operations, topsoil occurring on areas identified as prime farmland must be separately segregated and replaced during reconstruction of the prime farmland. The A soil horizon, then the B and C soil horizons, either separately or in combination, or other suitable material that will allow for reconstruction of a root zone of equal or greater productive capability to that existing prior to mining must be separately removed. If stockpiling of the soil horizon material is necessary each horizon or combination of horizons separately removed must be separately stockpiled and properly identified. During replacement, the C horizon material and then the B horizon material or a combination thereof will be replaced first. The A horizon material shall be replaced as the surface layer. The administrator may approve a plan which does not provide for the segregation of soil horizons if the applicant can document by acceptable scientific means that removal of all topsoil in one step would not diminish prime farmland restoration objectives of restoring equivalent or higher cropping yields. Prior to replacement of topsoil the regraded land surface shall be scarified. Excess compaction during topsoil replacement must be avoided so that permeability of the upper 20 inches of the topsoil is not reduced to less than 0.06 inches per hour.

b. Subsoil

(1). If no topsoil is present in the permit area, or in the event that an operator must use subsoil for final cover, the operator shall obtain an adequate number of analyses of the subsoil to show pH, organic material content, available nitrogen, potassium, and phosphorus and such other elements and soil constituents as the administrator shall require, over

the entire area of subsoil to be used, in order to determine suitability and fertilizer requirements. If the results of said analyses demonstrate to the satisfaction of the administrator that revegetation can be accomplished using such subsoil, the administrator may approve the use of such subsoil as an addition to or substitute for topsoil for reclamation purposes.

(2). Subsoil stockpiles shall be segregated from topsoil and overburden piles and shall be marked with a legible sign containing the word "Subsoil" in letters no less than 6 inches high on all approach roads to such stockpiles. Said sign or signs shall be placed not more than 150 feet from all stockpiles of subsoil. Such signs shall be in place at the time stockpiling is begun.

(3). The operator shall indicate on his maps the location of all subsoil piles.

(4). If subsoil is to be used in reclamation as a substitute for topsoil, all large rocks and other waste material which may hinder redistribution shall be separated before stockpiling.

(5). If all or some subsoil is not to be used in reclamation as a substitute for or additive to the topsoil, this unused subsoil must be regarded as all other overburden material and will be subject to the reclamation provisions described under the following subsection.

c. Overburden, spoil and refuse

(1). All overburden, spoil material and refuse shall be segregated from the topsoil and subsoil and stockpiled in such a manner to facilitate the earliest reclamation consistent with the approved reclamation plan.

(2). All overburden, spoil material, and refuse piles must be designed, graded, and contoured so as to blend in with the topography of the surrounding terrain. After the grading and contouring of these stockpiles, topsoil, or approved subsoil must be distributed over them in preparation for the revegetation procedures. The slopes of all spoil areas must be designed so that they will be stabilized against wind and water erosion. This may include terracing, channeling around the toe of the spoil piles or other techniques.

(3). Piles of spoil material or other waste shall be marked with a legible sign containing the word "Spoil" or the words "Waste Material" in letters no less than 6 inches high on all approach roads to such spoil piles. Said sign or signs shall be placed not more than 150 feet from all stockpiles.

Such signs shall be in place at the time when piling of spoil or waste material is begun.

(4). All topsoil shall be removed from areas to be used for piling spoil material prior to the beginning of piling this material.

(5). The operator may be required to have analyses made of spoil material in order to determine if it will be a source of water pollution through reaction with leaching by surface water. If it is determined that this condition may exist, the operator shall describe proposed procedures for eliminating this condition.

(6). The operator must also indicate on his maps the location and size of all proposed spoil piles.

(7). All overburden and spoil material, that is determined to be toxic, acid forming or will prevent adequate reestablishment of vegetation on the reclaimed land surface, unless such materials occur naturally on the land surface, must be properly disposed of during the mining operation.

(8). For surface coal mining operations, all overburden and spoil must be selectively placed and compacted wherever necessary to achieve stability of the reclaimed land surface and to prevent leaching of toxic materials into surface and ground waters.

(9). For surface coal mining operations, all spoil piles must be placed back into the pit, all highwalls eliminated, and the approximate original contours restored unless:

(a) The applicant or permittee can demonstrate that all of the spoil is not required to restore the approximate original contours or to achieve postmining contours which are consistent with an approved change in the postmining land use. Spoil not required to achieve the approximate original contours shall not be placed in disposal areas that contain springs, perennial or intermittent streams, or seep areas. Wherever possible, disposal areas shall be relatively flat or moderately sloping and naturally stable. All spoil piles must be designed by recognized professional standards and certified and inspected by a registered professional engineer for stability. Contouring of the spoil pile must provide for drainage patterns that complement the surrounding terrain and provide for a long-term stability.

(b) The reclamation plan provides for a water impoundment. Where impoundments are approved, highwalls above the

shoreline of the impoundment shall be eliminated by grading to slopes which do not exceed 1:2 (vertical: horizontal), are stable, and can be reclaimed to the postmining land use.

d. Acid forming and toxic materials and refuse resulting from surface coal mining operations:

(1). A plan shall be submitted by the permittee for the disposal or treatment of acid forming or toxic materials, or materials constituting a fire, health, or safety hazard uncovered during or created by the mining process. Disposal or treatment of these materials shall be in a manner to prevent pollution of surface or subsurface water or threats to human or animal health and safety.

(2). Boreholes, shafts, wells and augerholes or other more or less horizontal holes shall be cased, sealed or otherwise managed to prevent mixing of ground waters of significantly different quality. All boreholes, that are within the permit area, but are outside the coal mining area or which extend beneath the coal to be mined and into water bearing strata, shall be plugged permanently in a manner approved by the Administrator, unless the boreholes have been approved for use in monitoring.

(6). All exposed coal seams remaining after mining and any acid forming, toxic and combustible materials, or any waste materials that are exposed, used or produced during mining shall be covered with a minimum of 4 feet of nontoxic and noncombustible material, or if necessary, treated.

Section 5. Revegetation.

a. Revegetation of all affected lands shall be accomplished in a manner consistent with the approved reclamation plan and the proposed future use of the land.

b. Land, which did not support vegetation prior to becoming affected land because of natural soil conditions, need not be revegetated unless subsoil from such affected land will support vegetation.

c. After backfilling, grading, and contouring and the replacement of topsoil, and/or approved substitute, in such a manner so as to most efficiently accommodate the retention of moisture and control erosion on all affected lands to be revegetated, any fertilizer requirements as determined on the basis of previous analyses must be fulfilled.

Seeding which is accomplished by mechanical drilling shall be on the contour unless specific situations dictate that other methods of seeding should be used.

d. The method of revegetation, including but not limited to species of plants, seeding rates, seeding techniques, mulching requirements, and seeding times to be used in a given area for reclamation purposes, shall be approved by the Land Quality Division. The standards and specifications adopted by the State Conservation Commission for mine reclamation shall be considered by the applicant during the preparation of the reclamation plan. Whenever practicable, the Wyoming Game and Fish Department and the Wyoming Department of Agriculture may be consulted regarding revegetation procedures. Seeding of affected lands shall be conducted during the first normal period for favorable planting conditions after final preparation unless an alternative plan is approved. Whenever a permanent cover of vegetation will not be seeded within 45 days, affected lands that have been topsoiled shall be seeded to a temporary cover or otherwise protected. Any rills or gullies that would preclude successful establishment of vegetation or achievement of postmining land use shall be removed or stabilized. The species of vegetation to be used in revegetation efforts shall be described in the reclamation plan indicating the composition of seed mixtures and the amount of seed to be distributed on the area on a per-acre basis. Seed types will depend on the climatic and soil conditions prevailing in the permit area and the proposed use of the land after reclamation. Species to be planted as permanent cover shall be self-renewing. Seeding rates will depend on seed types, climatic and soil conditions and the techniques to be used in seeding.

   For surface coal mining operations, mulch or an equivalent erosion control and water conservation technique shall be applied to all topsoiled areas.

e. More suitable species of vegetation may be substituted if revegetation test plot results show such species to be of superior value for reclamation purposes.

f. The Administrator shall not release the entire bond of any operator until such time as revegetation is completed, if revegetation is the method of reclamation as specified in the operator's approved reclamation plan. Revegetation shall be deemed to be complete when (1) the vegetative cover of the affected land is shown to be capable of renewing itself under natural conditions prevailing at the site, and is at least equal to the cover on the area before mining, (2) the productivity is at least equal to the productivity on the area before

mining, (3) the species diversity and composition are suitable for that land use goal, and (4) the requirements in (1), (2), and (3) are met for two consecutive years.

If reforestation for commercial harvest is the method of revegetation used, reforestation shall be deemed to be complete when ninety (90) percent of the population density goal of the reclamation plan has been achieved, the plants have shown themselves capable of continued growth of a period of five (5) years following planting, and the understory vegetation is adequate to control erosion and is appropriate for the land use goal.

When the approved reclamation plan is to return to cropland, reclamation shall be deemed to be complete when production is equivalent, for at least two consecutive crop years, to the production on an approved reference area in the vicinity. In addition, the premining production data on the reclaimed site shall be considered in judging completeness of reclamation whenever said data are available.

For surface coal mining operations, the bond for revegetation may be retained for ten (10) or more years after the last seeding; or in the case of cropland, after the first seeding.

g. Any plans for irrigation must meet State laws for this use and be explained in the reclamation plan.

h. The operator must protect young vegetative growth from being destroyed by livestock by fencing or other approved techniques for a period of at least two (2) years, or until the vegetation is capable of renewing itself with properly managed grazing and without supplemental irrigation or fertilization.

i. In those areas where there were no or very few noxious weeds prior to being affected by mining, the operator must control and prevent the introduction of noxious weeds into the revegetated areas for a period of at least five (5) years after the initial seeding.

## CHAPTER III

## WATER DIVERSION, USES, IMPOUNDMENTS

### Section 1. Diversion of unchannelized surface waters

a. Surface water shall be diverted around the operation for the following purposes:

(1) To control water pollution.
(2) To control unnecessary erosion.
(3) To protect the ongoing operation.
(4) To protect the water rights of downstream users.

b. Temporary diversion structures are those used during mining and reclamation, and when no longer needed, they shall be removed and the area reclaimed.

c. In no case shall diversion ditches discharge upon topsoil storage areas, spoil or other unconsolidated material such as newly reclaimed areas.

d. A description of surface water diversion systems must be included in the mining plan and reclamation of these systems must be described in the reclamation plan.

e. Permanent diversion structures shall pass the peak runoff from a 100-year precipitation event, or larger, as specified by the Administrator.

Section 2. Diversion of streams

a. In no case shall spoil, topsoil, or other unconsolidated material be pushed into or placed below the flood level of a perennial or intermittent stream except during the approved construction of the diversion of said stream.

c. The Wyoming Game and Fish Department shall be consulted prior to the approval of a diversion of a perennial or intermittent stream.

f. Permanent diversion of a perennial stream must be fully described in the mining or reclamation plan.

g. Mining on the flood plain of a perennial or intermittent stream shall not be permitted if it would cause the uncontrolled diversion of the stream during periods of high water.

h. Waters flowing through or by the mining operation shall meet the standards set by the U.S. Environmental Protection Agency and the Wyoming Water Quality Division.

i. For coal mining operations, all land within 100 feet of a perennial or intermittent stream shall not be disturbed unless specifically authorized by the Administrator.

Section 3. Surface waters

a. The operator shall list and describe the name, location, size, and approximate intermittent flow intervals for the

present surface waters in and adjacent to the proposed permit area. The list shall include, but not be limited to, rivers, creeks, lakes, reservoirs, springs and marshes.

b. Monitoring surface water conditions may be required during the course of the proposed operation based on the existing water conditions and the nature of the proposed operation.

Section 4. Subsurface waters

a. The operator shall submit an estimate of the depth and quantity of any subsurface waters existing in the proposed permit area.

b. For coal mining operations, infiltration rates, subsurface flow and storage characteristics, and the quality of ground water shall be monitored to determine the effects of mining and reclamation operations on the recharge capacity of reclaimed lands and on the quantity and quality of water in ground water systems at the mine area and in associated offsite areas. When operations are conducted in such a manner that may affect the ground water system, ground water levels and ground water quality shall be periodically monitored using wells that can adequately reflect changes in ground water quantity and quality resulting from such operations.

Section 6. Water impoundments

a. Water impoundments may be considered as final reclamation when it can be shown that their construction is an approved use of the land after reclamation and the proposed impoundments are part of the approved plan in accordance with the provisions of the statutes and these regulations.

d. All proposed water impoundments and dams to be constructed for reclamation purposes must be approved by the State Engineer's Office.

Section 8. Water quality standards, effluent limitations, and sedimentation control for coal mining operations

a. All surface drainage from disturbed areas (excluding sedimentation ponds, diversion ditches, or road disturbances) shall pass through a sedimentation pond(s) before leaving the permit area. Sedimentation ponds shall be constructed prior to mining activity disturbance and shall be retained until the area has been successfully reclaimed, or until erosion movement on such disturbed areas does not exceed "t" values which would be allowed on similar soils and slopes under natural conditions. Discharge from the disturbed area for all events less than the 10-year, 24-hour storm shall meet Federal and State effluent standards.

b. The requirement for downstream erosion control practices shall reflect the degree to which successful techniques have been applied at the sources of sediment.

c. Sedimentation ponds should be located as near as possible to the affected lands and out of major stream courses.

d. An additional sediment storage volume must be provided which is equal to a minimum of 3 years of accumulated sediment from the affected lands to the pond.

Section 9. Water monitoring for coal mining operations

Sufficient data to describe the likely variations of water flow, pH, total iron, total manganese, total suspended solids, and any other parameter requested by the Administrator shall be monitored before and during mining operations and during and after reclamation as required by the Administrator. The permittee is responsible for properly installing, operating, maintaining, and removing all necessary monitoring equipment.

Section 10. Alluvial valley floors for surface coal mining operations

a. Coal mining operations conducted in or adjacent to alluvial valley floors shall be planned and conducted so as to preserve the essential hydrologic functions of these alluvial valley floors throughout the mining and reclamation process. These functions shall be preserved by maintaining or reestablishing those hydrologic and biologic characteristics of the alluvial valley floor that are necessary to support the function. The permittee shall provide information to the Administrator to allow identification of essential hydrologic functions and demonstrate that the functions will be preserved.

b. Coal mining operations shall not interrupt, discontinue, or preclude farming on alluvial valley floors and shall not materially damage the quantity or quality of surface or ground water that supplies these valley floors unless the premining land use is undeveloped rangeland which is not significant to farming on the alluvial valley floor or unless the area of affected alluvial valley floor is small and provides negligible support for the production from one or more farms.

## OBJECTIVE OF RECLAMATION

Mine operators must comply with all established Reclamation laws. Federal mining regulations are the minimum that are acceptable and they may be superseded by more stringent State regulations. These laws and regulations set forth the main objective that must be fulfilled by Reclamation programs.

Section 816.133, Subchapter K, Chapter VII of 30 CFR (Federal regulations) in part states:

> "All affected areas shall be restored in a timely manner: (1) to conditions that are capable of supporting the uses which they were capable of supporting before any mining; or (2) to higher or better uses achievable under established regulations."

Section 1, Chapter II of the 1978 Land Quality Rules and Regulations of the Department of Environmental Quality (Wyoming) requires that:

> "All lands affected by any aspect of a mining operation after July 1, 1973, must be reclaimed to a use equal to or greater than the highest previous use of the land prior to the land being affected by mining."

Both Federal and State regulations present specific guidelines for determining premining land uses and acceptable postmining uses.

The objective of all reclamation programs is, therefore, to restore the mined land to these uses and productivity goals.

## PHYSICAL PROFILE

### CLIMATE

#### General

The White Tail Butte Study Area has a continental-type climate characterized by cold winters, warm summers, and large variations in seasonal precipitation. The Recluse NNW Weather Station, Latitude 44°56', Longitude 105°48', is the primary source of weather data. The elevation at the station is 3752.6 feet. Weather conditions in the study area, which is about 11 miles east of the station, should be very similar.

The mountains along the Continental Divide west of the study area cause air masses to rise and precipitate their moisture. As a result, a rain shadow is created in eastern Wyoming. The mean annual precipitation recorded at stations within a 40-mile radius of the study area ranges from 12.5 to 19.1 inches.

#### Temperature

Maximum and minimum temperatures recorded at the Recluse NNW Station are 107.6°F and -43.6°F. The mean monthly and annual temperatures (based on average daily temperatures) for the 1967-76 period are:

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °F | 15.4 | 24.3 | 32.4 | 42.4 | 51.8 | 60.8 | 69.8 | 69.8 | 57.2 | 43.9 | 31.3 | 19.2 | 43.2 |

The growing season for hardy crops and native grasses is about 21 days longer than the frost-free period. Information related to the growing season/frost-free period is listed in the following tabulation:

Average Dates

| Station | Min. Daily Temp. °F | Last Spring | First Fall | Days Between | Years of Record |
|---|---|---|---|---|---|
| Recluse NNW | 32° | May 25 | Sept. 17 | 115 1/ | 1967-1976 |
| Recluse NNW | 28° | May 14 | Sept. 22 | 136 2/ | 1967-1976 |

#### Precipitation

The average annual precipitation at the Recluse NNW station is 16.3 inches. Precipitation in 60 percent of the years between 1967 and 1976 was above the annual average. The driest year was 1972 with 12.5 inches and the

1/ Frost-free period
2/ Growing season - hardy crops

wettest year was 1973 with 18.8 inches. The following tabulation lists the average monthly precipitation.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| in. | 0.7 | 0.7 | 0.7 | 2.1 | 2.7 | 3.0 | 1.5 | 1.1 | 1.2 | 1.4 | 0.7 | 0.5 |

About 72 percent of the precipitation falls during the months of April through September. The principal growing season, May to July, receives 38 percent of the annual precipitation. Late fall, winter, and early spring precipitation represent only 19 percent of the annual precipitation.

## Other Climatic Factors

Considerable sunshine can be expected during all seasons, except for a rainy period in May and June. July usually has the largest number of days with sunshine.

Thunderstorms and occasional hailstorms are most common in this area in July and August. Table 1 shows the potential storm intensity and frequency of occurrence in Powder River County, Montana. Similar storm occurrences and intensities are anticipated for the northern portion of Campbell County, Wyoming, a short distance away. These data also indicate the potential erosion hazard. Hail damage to native grasses is minimal.

## Effect of Climate on Revegetation

The climate of the study area is generally favorable for revegetation of surface-mined land with adapted plant species. The pregrowing season moisture, 2.1 inches, is stored in the root zone, and when combined with the principal growing season precipitation, 7.2 inches, promotes rapid growth of spring planted grasses and other plant species.

There is rarely enough stored soil moisture plus precipitation to produce maximum plant growth during the 136 day growing season for hardy crops (days above 28°F). Range plants usually deplete the available moisture by mid-July and mature or become dormant. Studies on the potential consumptive use of moisture by native grasses confirm this. Maximum production during this period would require about 23 inches of precipitation. This would be a 44 percent increase over average years.

The spring rains usually exceed the plant moisture requirement. This allows soluble salts to be leached to a depth below 2 feet in permeable soils. This nonsaline condition in the plant root zone is favorable for most plant species.

Climatic factors that may result in poor plant populations or planting failures are: (1) below normal or uneven distribution of precipitation, especially during the growing season, (2) thunderstorms or strong winds

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that cause erosion, (3) late spring freezes, and (4) depletion of soil moisture by wind. Careful planning prior to mining, and proper management following reclamation, can help reduce the adverse effects of these factors.

TABLE 1. ESTIMATED MAXIMUM AMOUNTS OF RAINFALL IN POWDER RIVER COUNTY MONTANA 1/ FOR STATED PERIODS OF DURATION AND 2/ THE FREQUENCY THAT THESE AMOUNTS OCCUR

(Based on Data from U.S. Weather Bureau Technical Paper No. 40(6))

| | Frequency of once in-- | | | | |
|---|---|---|---|---|---|
| Duration | 2 years Inches | 5 years Inches | 10 years Inches | 25 years Inches | 50 years Inches |
| 30 minutes----- | 0.6 | 0.9 | 1.1 | 1.3 | 1.5 |
| 1 hour--------- | 0.8 | 1.1 | 1.3 | 1.6 | 1.9 |
| 3 hours-------- | 1.0 | 1.5 | 1.7 | 2.0 | 2.5 |
| 6 hours-------- | 1.3 | 1.7 | 2.0 | 2.5 | 2.9 |
| 12 hours-------- | 1.5 | 2.0 | 2.4 | 2.8 | 3.3 |
| 24 hours-------- | 1.7 | 2.4 | 2.8 | 3.2 | 3.7 |

1/ Powder River County, Montana adjacent to Campbell County, Montana

2/ Soil Survey Powder Area - Montana-Soil Conservation Service (1971).

## PHYSIOGRAPHY

The White Tail Butte Study Area is in the Unglaciated Missouri Plateau section of the Great Plains Physiographic Province. The area is generally rolling and rather thoroughly dissected. Several prominent buttes, capped by resistant clinker, rise above a tabular divide which generally trends in a northwesterly direction through the study area. The most prominent of these clinker-capped buttes is White Tail Butte, located in sections 31 and 32, T. 56 N., R. 72 W. Relief in the study area is about 1260 feet, with elevations ranging from 3090 feet in an unnamed draw on the north side of the area to 4350 feet on top of White Tail Butte.

The study area is situated on the drainage divide between Elk Creek to the north and White Tail Creek to the south. Both Creeks are intermittent and flow in an eastward direction to the Little Powder River. The Little Powder River is a tributary of the Powder River, which enters the Yellowstone River west of Terry, Montana. Drainages within the study area are deeply incised into shales and sandstones of the Wasatch (Eocene) and Fort Union (Paleocene) Formations. The dendritic drainage system and stream orders are shown on Plate 4. Features typical of the terrain are shown on Photographs 2 through 6.

# GEOLOGY

## Regional Geology

The White Tail Butte Study Area is located in the eastern part of the Powder River Basin in northeastern Wyoming. This basin, a part of the unglaciated portion of the Great Plains physiographic province, is about 225 miles long, extending from the Yellowstone River in Montana to the North Platte River in Wyoming. It is about 90 miles wide, bounded on the west by the Bighorn Mountains and on the east by the Black Hills. Structurally, the basin is an asymmetrical syncline with a northwestward trending axis. An estimated 18,000 feet of sediments overlie the basement complex in the deepest part of the basin north of Glenrock, Wyoming.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. During the Paleozoic and Mesozoic Eras, a sequence of carbonates, sandstones, and shales were deposited throughout Montana and Wyoming. Thickness of these sediments on the west side of the basin varies from 9,000 feet near Yellowtail Dam to 11,500 feet near Buffalo, Wyoming. About 6,500 feet of Paleozoic and Mesozoic sediments are present in the Black Hills area on the east side of the basin.

The area was relatively stable during these periods with deposition occurring generally under a marine environment. Deformation of these strata began with the Laramide Revolution near the close of the Mesozoic Era (Late Cretaceous), at which time mountain masses such as the Bighorns and Black Hills were uplifted. Uplift continued through Paleocene and gradually ended in Eocene time. Materials stripped from the mountains were deposited in fans or sheets across the basin floors, gradually burying the flanks of the mountains in their own debris. By the middle of the Cenozoic Era, the basins were largely filled and the mountains peneplained. In Pliocene time, a broad regional uplift occurred and continued intermittently into Pleistocene time. This uplift raised the previously developed peneplain surface to elevations of about 10,000 feet in the Bighorn Mountains. Streams rejuvenated by the uplift excavated the basins and exhumed the buried mountain masses.

Today, Precambrian rocks are exposed in the cores of the Black Hills and Bighorn Mountains. These rocks are surrounded by sediments of Paleozoic and Mesozoic Age. The central part of the basin is filled with Cenozoic (Tertiary) sediments. Plate 5 is a generalized map of the regional geology of the basin area.

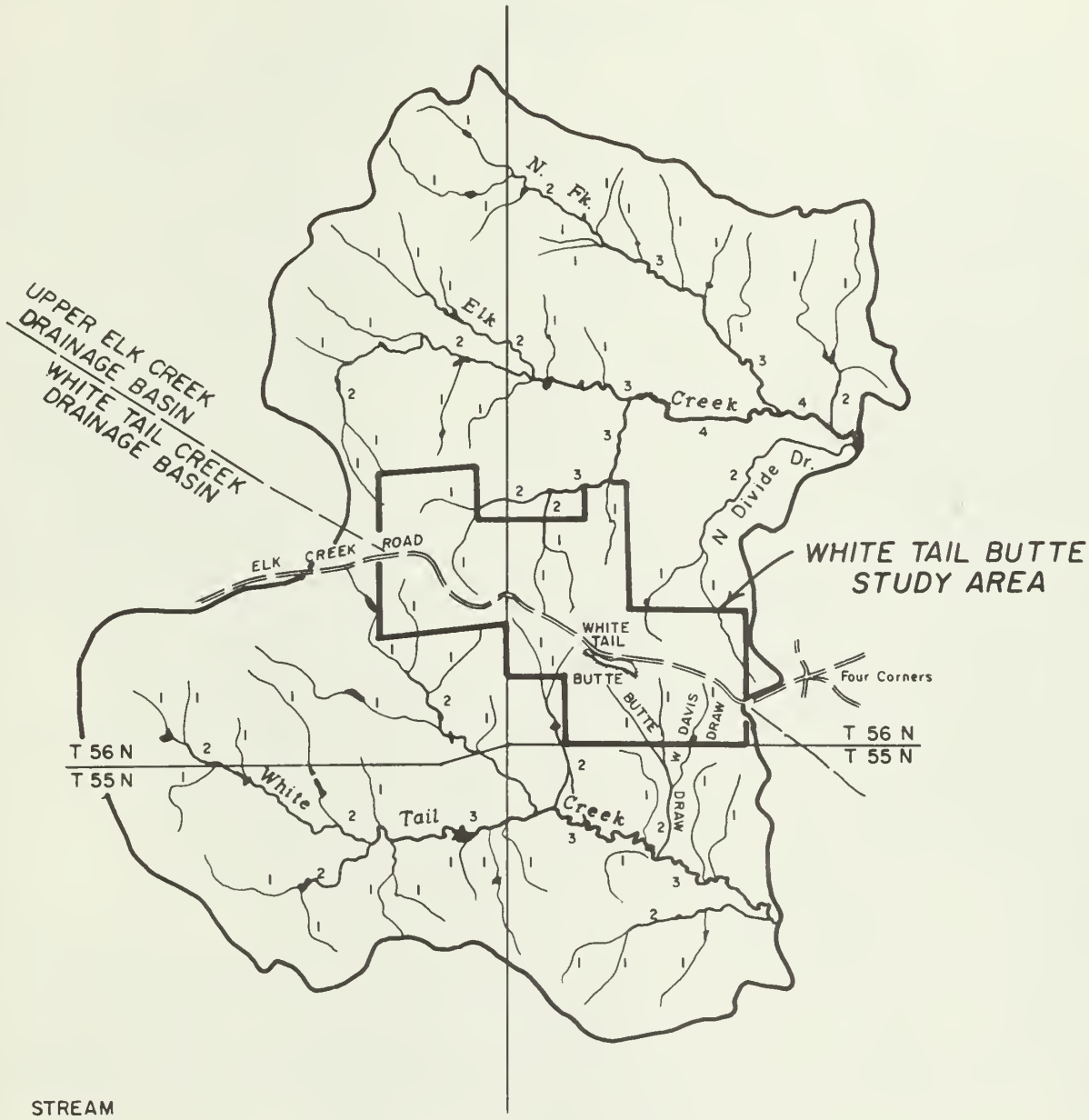
Photograph 2 - WHITE TAIL BUTTE STUDY AREA - LITTLE POWDER RIVER COALFIELD, WYOMING - Panoramic view of the North Divide Draw in Section 29, T. 56 N., R. 72 W. Photograph taken from resistant Wasatch bench near Drill Hole 76-102.
U. S. Bureau of Reclamation Photograph P1305-600-13 6/29/76

Photograph 3 - WHITE TAIL BUTTE STUDY AREA - LITTLE POWDER RIVER COALFIELD, WYOMING - View looking west into study area from Drill Hole 76-102. Butte on right side of photograph is capped by Felix Clinker. Light colored resistant ledge on left side is lower part of Wasatch Fm. (Eocene). Shales of the Tongue River Member-Ft. Union Fm. (Paleocene) crop out on slopes below.
U. S. Bureau of Reclamation Photograph P1305-600-14 6/29/76

Photograph 4 - WHITE TAIL BUTTE STUDY AREA - LITTLE POWDER RIVER COALFIELD, WYOMING - View looking north at rounded knobs of Anderson Clinker. Photograph taken from roadway in southwest corner of Section 30, T. 56 N., R. 72 W.
U. S. Bureau of Reclamation Photograph P1305-600-15 6/29/76

Photograph 5 - WHITE TAIL BUTTE STUDY AREA - LITTLE POWDER RIVER COALFIELD, WYOMING - View looking southwest from Drill Hole 76-102 towards White Tail Butte. Butte is capped by Felix Clinker. Base of Wasatch Fm. (Eocene) is light colored ledge immediately below roadway. Ft. Union shales (Paleocene) form canyon slopes.
U. S. Bureau of Reclamation Photograph P1305-600-16 6/29/76

Photograph 6 - WHITE TAIL BUTTE STUDY AREA - LITTLE POWDER RIVER COALFIELD, WYOMING - View looking north from Drill Hole 76-103 towards White Tail Butte.
U. S. Bureau of Reclamation Photograph P1305-600-17 6/29/76




STREAM ORDER

| | |
|---|---|
| 1 | Smallest tributary 1/ |
| 2 | Channel segment where 2 1st order tributaries join. |
| 3 | Channel segment where 2 2nd order tributaries join. |
| 4 | Channel segment where 2 3rd order tributaries join. |
| ● | Ponds |

1/ Shown as intermittent stream on USGS 7.5' quadrangle.

1: 90000

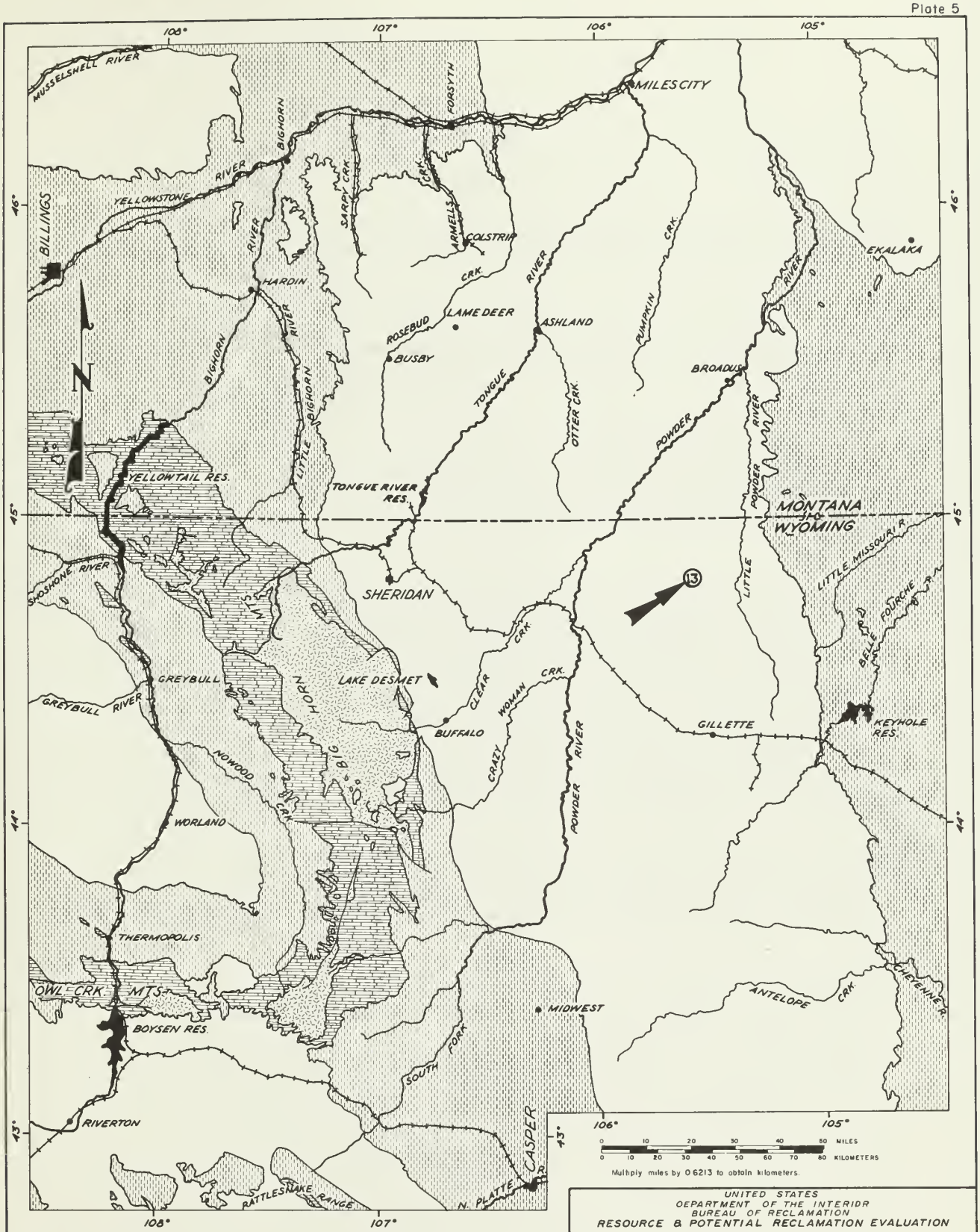
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING

**DESIGNATION OF STREAM ORDER**

DRAWN HB WARD SUBMITTED
TRACED LE ALLSOP RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY, 1978 1305-600-137


108°
107°
106°
105°
46°
45°
44°
43°
MUSSELSHELL RIVER
MILES CITY
FORSYTH
BIGHORN
RIVER
YELLOWSTONE
BILLINGS
SARPY CRK.
ARMELLS CRK.
COLSTRIP
HARDIN
LAME DEER
ROSEBUD CRK.
BUSBY
ASHLAND
TONGUE RIVER
PUMPKIN CRK.
OTTER CRK.
BROADUS
POWDER RIVER
EKALAKA
LITTLE BIGHORN RIVER
YELLOWTAIL RES.
TONGUE RIVER RES.
MONTANA
WYOMING
LITTLE POWDER RIVER
LITTLE MISSOURI R.
BELLE FOURCHE R.
SHOSHONE RIVER
SHERIDAN
BIG HORN MTS.
LAKE DESMET
CLEAR CRK.
WOMAN CRK.
GREYBULL
GREYBULL RIVER
BUFFALO
CRAZY
GILLETTE
KEYHOLE RES.
NOWOOD CRK.
WORLAND
THERMOPOLIS
OWL CRK. MTS.
BOYSEN RES.
MIDWEST
ANTELOPE CRK.
CHEYENNE R.
SOUTH FORK
RIVERTON
CASPER
N. PLATTE R.
RATTLESNAKE RANGE
13
0 10 20 30 40 50 MILES
0 10 20 30 40 50 60 70 80 KILOMETERS
Multiply miles by 0.6213 to obtain kilometers.
CENOZOIC
MESOZOIC
PALEOZOIC
PRE-CAMBRIAN
NOTE: COMPILED FROM STATE GEOLOGIC MAPS
13 WHITE TAIL BUTTE STUDY AREA-EMRIA NO. 13
UNITED STATES
DEPARTMENT OF THE INTERIOR
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RESOURCE & POTENTIAL RECLAMATION EVALUATION
EMRIA STUDY AREA
MONTANA-WYOMING
GENERALIZED
REGIONAL GEOLOGIC MAP
GEOLOGY G.J. TAUCHER
DRAWN G.J. TAUCHER
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
BILLINGS, MONTANA MARCH 1976
1305-600-36

## Area Geology

### Investigations

All of the area involved in the White Tail Butte Study Area has been mapped by the U.S. Geological Survey. Publications covering these investigations are listed in the bibliography.

Geologic investigations were conducted in the study area by the U.S. Bureau of Reclamation (now Water and Power Resources Service) between June of 1976 and March of 1977. These investigations included mapping the surface geology and drilling eight core holes.

Detailed geologic mapping on a scale of 1 to 12,000 was completed in the field on aerial photographs. These data were transferred to a topographic map of the same scale and are shown on Plate 7. Plate 6 shows a generalized stratigraphic column of coal and carbonaceous beds mapped or penetrated by drilling.

Eight drill holes ranging from 275.0 to 785.5 feet in depth were completed in the study area. Continuous cores were obtained from all holes for geologic logging and for the selection of coal and overburden samples for laboratory analyses. Locations of the drill holes are shown on the Geologic and Investigations Map, Plate 7. Geologic cross sections, correlating coalbeds, are shown on Plates 8 and 9. Detailed geologic logs for drill holes are listed on Plates 10 through 22, Appendix B. Funding was obtained by the Coal Resource Branch of the U.S. Geological Survey to deepen Drill Holes 76-103 and -108 approximately 450 feet through the Cook, Wall, Pawnee and Cache Coalbeds. Core descriptions are included on the geologic logs in Appendix B.

Two-inch-diameter metal pipe was installed in Drill Holes 76-102 and -103 for ground water studies. These studies are being conducted by the Water Resource Division of the U.S. Geological Survey and will require several years to complete.

The core drilling was performed using Failing Models 314 and 750 rotary drill rigs. Wireline drill tools with an "H" series barrel were used to recover core samples in most holes. Nx and Bx size wireline cores were obtained where reduction of the hole (DH 76-103 and -108) was necessary. Use of drilling tools larger than the standard exploratory sizes was dictated by (1) necessity to maximize core recovery, (2) provide sufficient sample for laboratory and greenhouse studies from zones as thin as 5 feet, and (3) to minimize the contamination potential. Reaming was necessary in holes where casing was required.

Most of the drilling was accomplished using bottom discharge bits set with tungsten carbide inserts. Both preset and field set bits were used. The chief advantage of field setting is better control of bit gage, both inside and outside, which in some of the softer rocks can be used to increase core recovery.

The recovered drill cores were placed in 5-foot-long core boxes and covered by a sheet of 4-mil polyethylene plastic. This prevented a loss of moisture and a change of physical state in the drill core until logging and sampling could be accomplished.

Water from a well near Recluse, Wyoming, was used as the drilling fluid in all drill holes. This required a haul of about 10 miles to the area. Tests conducted by the U.S. Bureau of Reclamation (now Water and Power Resources Service) soils laboratory in Miles City, Montana, indicated that the concentrations of dissolved solids ranged from 760 to 840 mg/l for the well water.

Field checks made by adding a fluorescent dye (Fluorescein) to the drill water and checking the obtained cores under an ultraviolet light indicate that penetration by the drill fluid, if any, is less than 1 millimeter in permeable sandstone and can be readily removed in sample preparation. Impermeable siltstone and shale samples showed no evidence of dye contamination.

## Stratigraphy

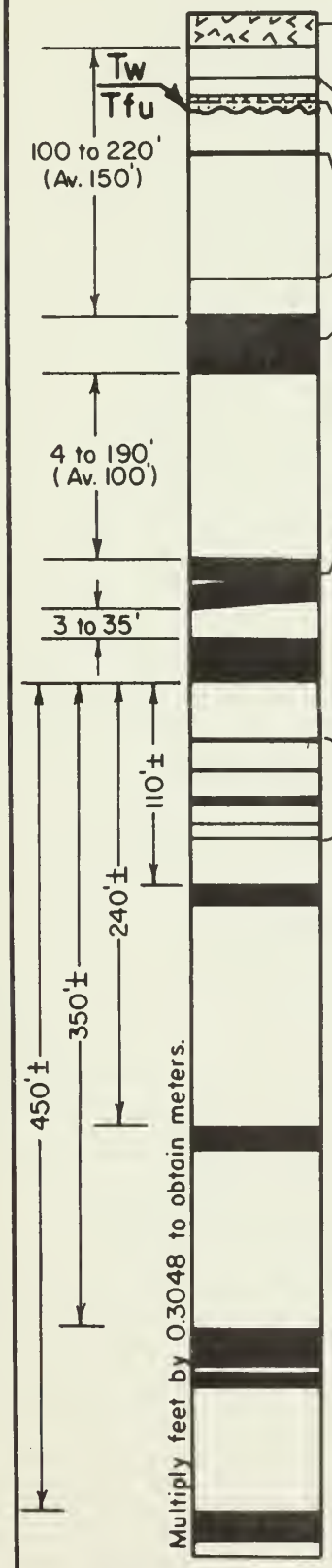
Sedimentary rocks exposed in the study area range from Paleocene to Holocene in age. These include the coal bearing Fort Union Formation of Paleocene Age and the Wasatch Formation of Eocene Age. Alluvial deposits of Holocene Age mantle valley floors of the major tributaries.

### Paleocene Series

The Fort Union Formation consists of three lithologic units which include, from bottom to top, the Tullock, Lebo Shale and Tongue River Members. Only the Tongue River Member will be discussed in this report as the lower members were not penetrated by drilling, nor do they outcrop within the study area.

The Tongue River Member consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale and coal with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine grained and uncemented except for lenticular, concretionary masses of small lateral extent. Shales vary from soft, plastic clayshale to moderately indurated claystone. The shale and siltstone zones break down readily and form slopes below sandstone ledges. Correlation of clastic sediments over short distances is difficult due to facies changes, channeling, and variation in bedding thickness. Laboratory analyses conducted on core samples from the White Tail Butte Study Area indicate that chemical and physical properties of the bedrock cannot generally be projected between drill holes. Weathered exposures are pale olive or yellowish gray in color, while fresh core samples vary from light to dark gray. The Tongue River sediments were deposited in a continental environment which included swamps conducive to the production of thick coalbeds. Coal and carbonaceous zones serve as excellent marker beds as they can generally be traced laterally over great distances. Regional mapping indicates that the upper part of the Tongue River Member

# STRATIGRAPHIC COLUMN - COAL AND CARBONACEOUS SHALE BEDS WHITE TAIL BUTTE STUDY AREA - LITTLE POWDER RIVER COALFIELD WYOMING




A FELIX(?) CLINKER - 20 to 40 feet thick. Locally contains leaf prints. Caps buttes in study area.

B 1 to 2 feet of coal and carbonaceous shale. 20± feet below bed A.

Resistant sandstone, siltstone and silty shale. 10± feet thick. 3 to 25 feet above bed C. Unconformity(?) at base.

C SMITH COALBED - 1/2 to 2 feet of coal. 40 to 170 feet (Average 90 feet) above Anderson Coalbed.

D Up to 1-1/2 feet of coal. Locally splits into several beds. About 20 feet above Anderson Coalbed.

E ANDERSON COALBED - 30.0 to 37.3 feet thick. (Average 34.3 feet thick). Locally contains thin shale partings.

F DIETZ(?) COALBED - 14.7 to 28.2 feet thick. (Average 20.5 feet thick). Splits in western part of area. Thins westward. Also called Canyon "A" in U.S.G.S. reports.

G CANYON COALBED - 19.5 to 25.1 feet thick. (Average 21.6 feet thick). Also called Canyon "B" in U.S.G.S. reports.

H COOK COAL ZONE - A series of thin coal beds up to 7 feet thick occuring between G and I Coalbeds.

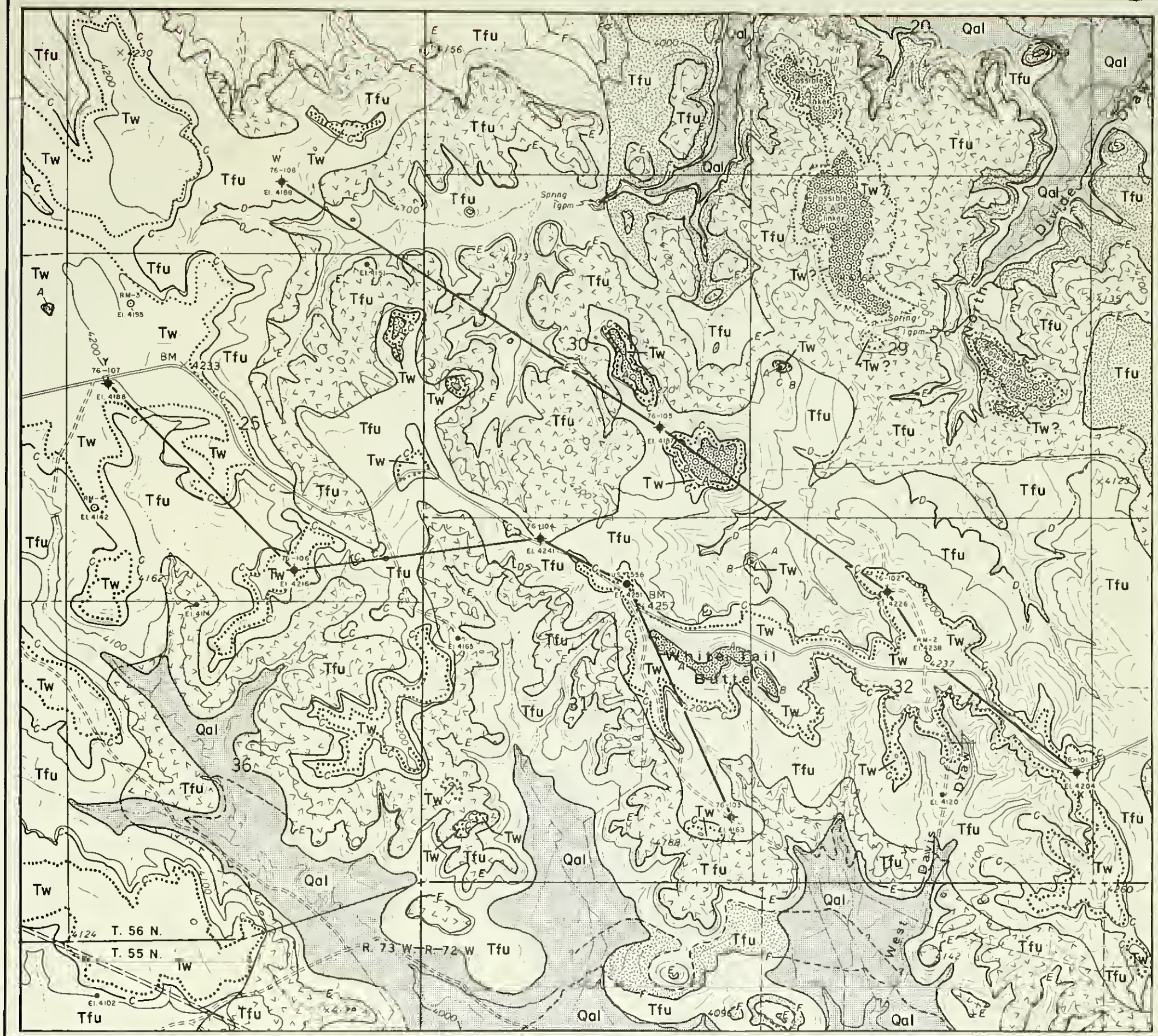
I UNNAMED COALBED - 11± feet thick. Contains several thin shale stringers.

J WALL COALBED - 11± feet thick.

K PAWNEE COALBED - 27± feet thick. Contains shale parting in lower part.

L CACHE COALBED - 16± feet thick.

PORTIONS OF WASATCH FM. OF EOCENE AGE (Tw) AND FT. UNION FM. - TONGUE RIVER MEMBER OF PALEOCENE AGE (Tfu)




## EXPLANATION

**HOLOCENE** — Qal — ALLUVIUM – Clay, silt, sand and gravel. Up to 30 feet thick.

**EOCENE** — Tw — WASATCH FM. – Interbedded shale, siltstone, sandstone and coal. Up to 100 feet exposed along buttes in study area. Includes baked sediments (clinker) produced by burning of coalbeds.

FELIX ? (A) Clinker

**PALEOCENE** — Tfu — FT. UNION FM. TONGUE RIVER MEMBER – Interbedded shale, siltstone, sandstone and coal. About 1200 feet thick. Includes baked sediments (clinker) produced by burning of coalbeds.

ANDERSON (E) Clinker

DIETZ ? (F) Clinker

—A to F— Base of coalbed or base of clinker where coal has been burned.

——— Geologic contact. Dashed where inferred.

····· Wasatch (Tw) – Ft. Union (Tfu) contact.

W–X, Y–Z Limits of geologic section.

✦ U.S.B.R. Drill Hole

⊙ U.S.G.S. Drill Hole

● Montana Bureau of Mines Drill Hole

• Abandoned oil well (Only wells where geologic data is available are shown.)

Notes:

1. Coal Resource Branch of U.S.G.S. supplied geologic data for drill holes other than those completed by U.S.B.R.
2. See Plate No. 6 for description of coalbeds.
3. Multiply feet by 0.3048 to obtain meters.

N

0 1000 2000 3000 FEET
0 300 600 900 METERS

Topography from U.S.G.S. White Tail Butte Quadrangle.

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RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

**GEOLOGIC AND INVESTIGATIONS MAP**

GEOLOGY G. J. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA JAN., 1977 1305-600-118

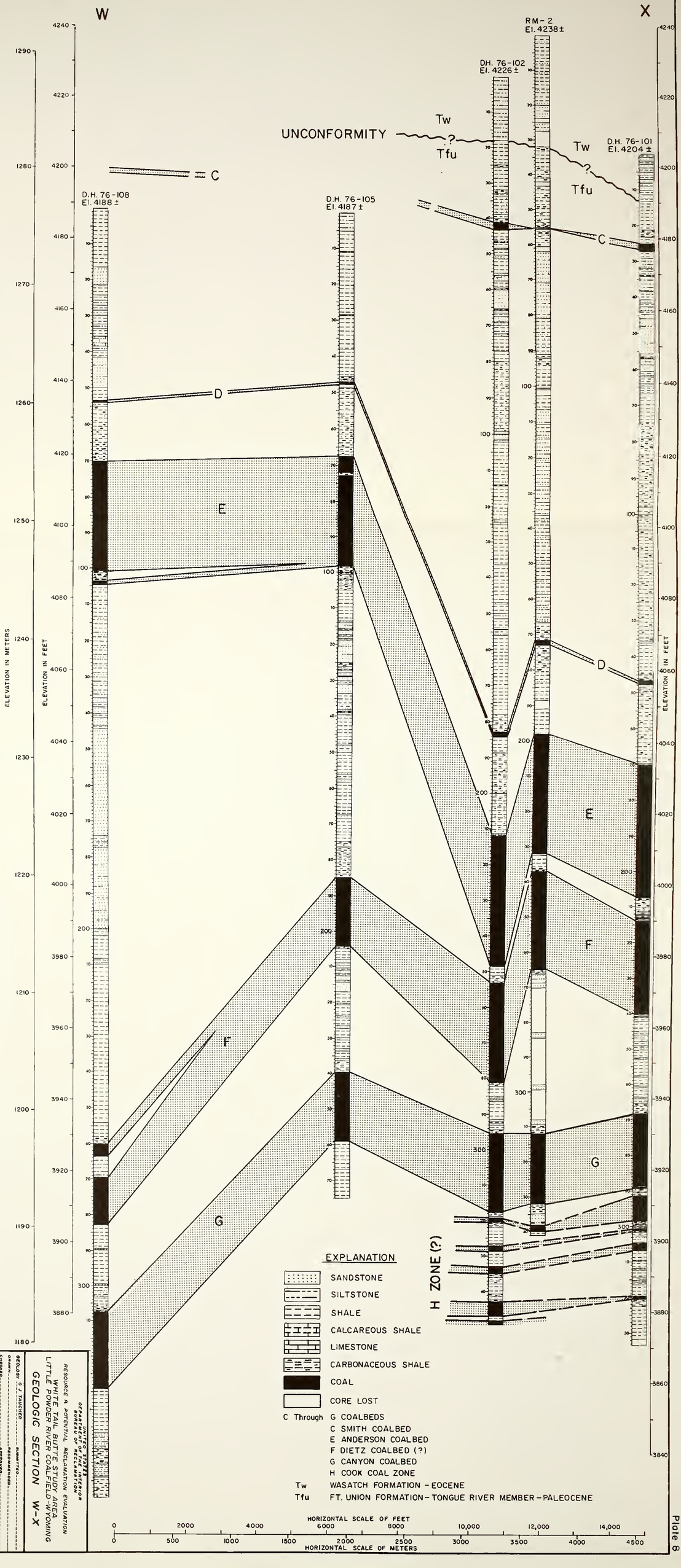
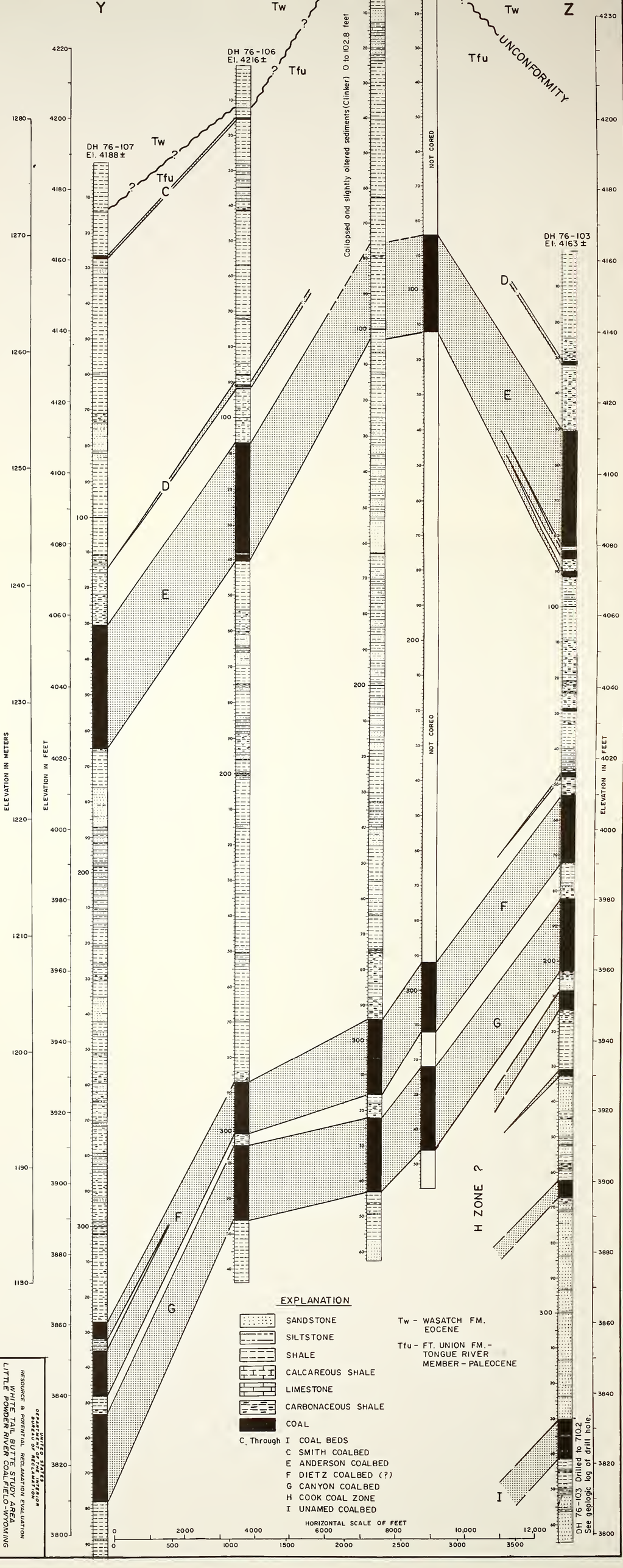

W
X
D.H. 76-108
El. 4188 ±
D.H. 76-105
El. 4187 ±
DH. 76-102
El. 4226 ±
RM-2
El. 4238 ±
D.H. 76-101
El. 4204 ±
UNCONFORMITY
Tw
Tfu
C
D
E
F
G
H ZONE (?)
ELEVATION IN METERS
ELEVATION IN FEET
NOTE: Depth on graphic logs in feet. Multiply feet by 0.3048 to obtain meters
EXPLANATION
SANDSTONE
SILTSTONE
SHALE
CALCAREOUS SHALE
LIMESTONE
CARBONACEOUS SHALE
COAL
CORE LOST
C Through G COALBEDS
C SMITH COALBED
E ANDERSON COALBED
F DIETZ COALBED (?)
G CANYON COALBED
H COOK COAL ZONE
Tw WASATCH FORMATION - EOCENE
Tfu FT. UNION FORMATION - TONGUE RIVER MEMBER - PALEOCENE
HORIZONTAL SCALE OF FEET
HORIZONTAL SCALE OF METERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD-WYOMING
GEOLOGIC SECTION W-X
BILLINGS, MONTANA
JAN 1977
305-600-119
GEOLOGY G.J. TAUCHER
DRAWN
CHECKED
RECOMMENDED
APPROVED
SUBMITTED

Plate 8




NOTE: Depth on graphic logs in feet. Multiply feet by 0.3048 to obtain meters

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RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD-WYOMING

GEOLOGIC SECTION Y-Z

DESIGNED J. TAUCHER
DRAWN
CHECKED
SUBMITTED
RECOMMENDED
APPROVED

BILLINGS, MONTANA JAN 1977

305-600-120

is missing within the study area either due to nondeposition or erosion. Thickness of the member is about 1200 feet in the area. Drilling at the White Tail Butte Study Area penetrated the upper 825 feet of the Tongue River Member.

### Eocene Series

The Wasatch Formation unconformably overlies the Tongue River Member within the study area. It consists of an alternating sequence of sandstone, siltstone, shale, and coal, similar in characteristics to the underlying Paleocene sediments. The base of a persistent ledge forming sandstone and siltstone lying from 3 to 23 feet above the Smith (C) coalbed was arbitrarily chosen as the contact between the Paleocene and Eocene sediments in the area. This contact was mapped on aerial photographs and plotted on the Geologic and Investigations Map, Plate 7. About 100 feet of Wasatch sediments are present along White Tail Butte, the highest point within the study area.

### Holocene Series

Alluvial deposits consisting of clay, silt, sand and gravel cover bedrock to depths of 30 feet along valley floors in the study area. Gravels are generally composed of hard shale, sandstone or clinker fragments.

## Clinker

One striking feature in the Fort Union and Wasatch Formations is the resistant clinker zones, locally called "scoria," that cap ridges and buttes or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of coalbeds along and back from the outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of coal that has burned. A coalbed 30 feet thick will produce clinker zones 50 to 75 feet thick. The clinker is highly permeable and locally supplies water for springs and wells. The three clinker zones present in the study area were produced by burning of the Felix, Anderson and Dietz Coalbeds. Outcrops of the Anderson and Dietz clinkers occur mostly along valley walls, while the Felix clinker caps the highest buttes within the area. Location of clinkered areas are shown on the Geologic and Investigations Map, Plate 7. Subsurface investigations at other sites show that not all coal has burned beneath clinkered areas. An extensive drilling program would be required to locate and delineate any such deposit. For the purpose of this report, the contact between baked and unbaked rock is assumed to be vertical and that all coal underlying clinker has burned.

## Coalbeds

Twelve persistent coalbeds, A through L, crop out or were penetrated by drilling in the White Tail Butte Study Area. Descriptions of these beds are found on the generalized stratigraphic column, Plate 6. Seven beds, A through G, were mapped in the study area as shown on the Geologic and Investigations Map, Plate 7. Only three beds of economic significance occur beneath the area within 200 feet of the surface. These include the Anderson (E), Dietz[1/] (F) and Canyon[2/] (G) Coalbeds.

The Anderson Coalbed averages 34.3 feet thick below overburden up to 200 feet thick in the study area. Contours showing depths to the Anderson Coalbed are plotted on the Overburden Thickness Map, Plate 23.

The Dietz Coalbed, which is over 28 feet thick in Drill Hole 76-102, splits into an upper and lower bench with a combined thickness of 18 feet in the western part of the area. The stratigraphic interval between the Anderson and Dietz beds ranges from 4.5 feet in Drill Hole 76-102 to 191 feet in Drill Hole 76-104. The Dietz may converge with the overlying Anderson or the underlying Canyon Coalbeds in the eastern part of the study area. Structure contours on top of the Dietz and overburden thickness contours indicating the depth to coal are shown on Plate 24.

The Canyon Coalbed averages 21.6 feet thick and lies from 3 to 35 feet below the Dietz Coalbed. Upper benches of the Cook coal zone lie stratigraphically near the Canyon bed and might be economically mineable in the eastern part of the area. Four coalbeds ranging from 11 to 27 feet thick were penetrated in drill holes beneath the Cook coal zone. These beds are of no significance under present surface mining methods. Structure and overburden thickness contours for the Canyon coalbed are shown on Plate 25.

## Structure

The study area is located on the east flank of the Powder River Basin. Regional dips in the area are toward the southwest away from the Black Hills at about 100 feet per mile. Structure contours drawn on coalbeds (Plates 23 through 25) show maximum dips of 200 feet per mile, or about 2 degrees. Small local folds within the area probably do not continue with depth and may be the result of either differential compaction or deposition.

Slickensides indicating minor localized faulting are evident in weak, plastic, carbonaceous shales above or below coalbeds. These features have less than 5 feet of displacement and are probably due to readjustment of material because of coalbed compaction. Surface mapping did not reveal any significant faulting.

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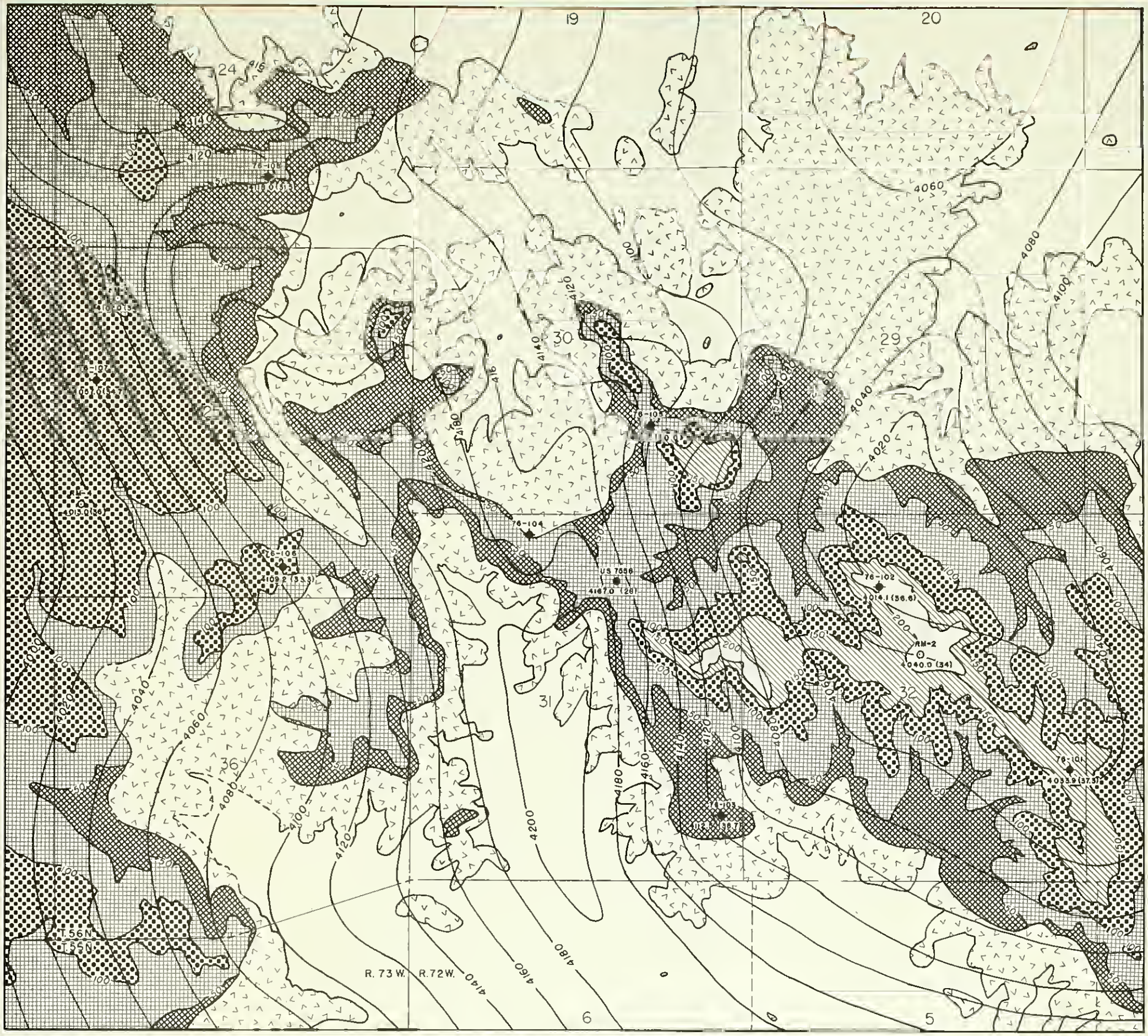
1/ Also called Canyon "A" in USGS reports
2/ Also called Canyon "B" in USGS reports




EXPLANATION

Clinker - Area where Anderson coal has burned

OVERBURDEN ABOVE ANDERSON COALBED

- 0 to 50 feet
- 50 to 100 feet
- 100 to 150 feet
- 150 to 200 feet
- over 200 feet

—4080— Structure contour on top of Anderson coalbed (feet)

—100— Contour showing depth to Anderson coalbed (feet)

U.S.B.R. Drill Hole

U.S.G.S. Drill Hole

Montana Bureau of Mines and Geology Drill Hole

Abandoned Oil Well (Only wells where geologic data is available are shown)

Note: Elevations adjacent to drill holes are for top of Anderson coalbed. Thickness of coal shown in parentheses.
Multiply feet by 0.3048 to obtain meters

SCALE

0 1000 2000 3000 FEET

0 300 600 900 METERS

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RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

**OVERBURDEN THICKNESS MAP**
ANDERSON COALBED

GEOLOGY G.J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA JAN. 1977 1305-600-134

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## Structure

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Slickensides indicating minor localized faulting are evident in weak, plastic, carbonaceous shales above or below coalbeds. These features have less than 5 feet of displacement and are probably due to readjustment of material because of coalbed compaction. Surface mapping did not reveal any significant faulting.

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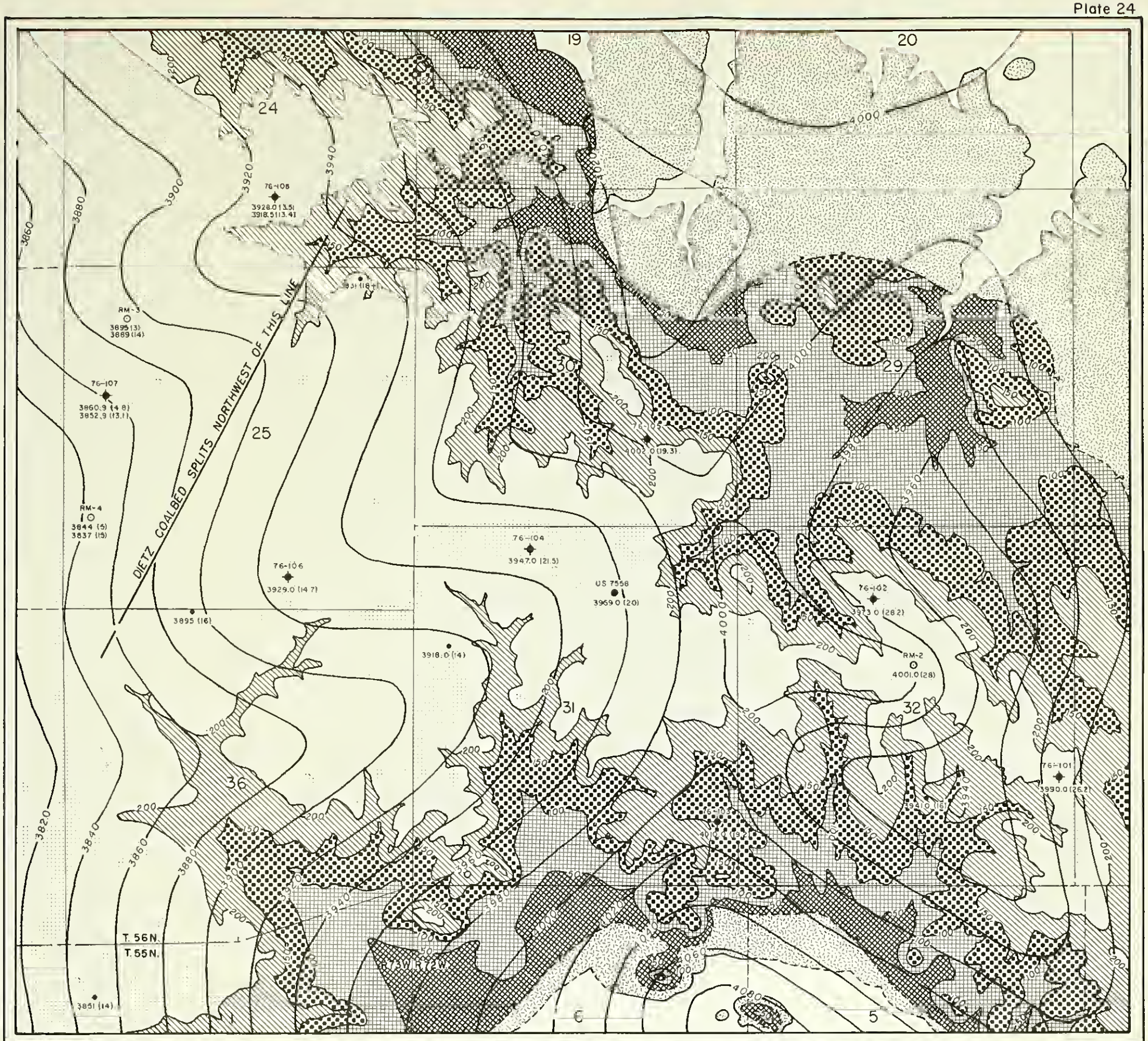
1/ Also called Canyon "A" in USGS reports
2/ Also called Canyon "B" in USGS reports




EXPLANATION

Clinker-Area where Dietz coalbed has burned

✱ OVERBURDEN ABOVE DIETZ COALBED

- 0 to 50 feet
- 50 to 100 feet
- 100 to 150 feet
- 150 to 200 feet
- over 200 feet

—3960— Structure contour on top of Dietz coalbed (feet).

—100— Contour showing depth to Dietz coalbed (feet).

Includes interburden, coal, and overburden

U.S.B.R. Drill Hole

U.S.G.S. Drill Hole

Montana Bureau of Mines and Geology Drill Hole

Abandoned oil well (Only wells where geologic data is available are shown)

Note: Elevations adjacent to drill holes are for top of Dietz coalbed.

Dual elevations represent tops of upper and lower benches where Dietz is split. Thickness of coal shown in parenthesis.

Multiply feet by 0.3048 to obtain meters.

SCALE

0 1000 2000 3000 FEET

0 300 600 900 METERS

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RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

✱ OVERBURDEN THICKNESS MAP
DIETZ COALBED

GEOLOGY G.J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA JAN., 1977 1305-600-135

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1/ Also called Canyon "A" in USGS reports
2/ Also called Canyon "B" in USGS reports

ALE

2000 3000 FEET

600 900 METERS

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BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

**OVERBURDEN THICKNESS MAP**
**ANDERSON COALBED**

GEOLOGY G.J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA JAN. 1977 1305-600-134

### Paleontology

Although fossil plants are common in the study area, none were found to be of unusual paleontological significance. Notable examples of plant remains include prints of fossil leaves that are well preserved in the Felix clinker deposits that cap White Tail Butte and poorly silicified, broken, tree trunks up to 6 inches in diameter that are found at random locations in the study area.

Fossil shells of mollusks, pelecypods and gastropods are common in calcareous shales and limestones. None of these were collected for identification.

## Engineering Geology

### Slope Stability

Engineering property tests were not conducted on bedrock samples from the White Tail Butte Study Area. However, physical properties of these sediments should be similar to the results obtained by the U.S. Geological Survey for Fort Union samples at the Otter Creek Study Site (EMRIA Report No. 1).

Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, namely along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage should be maintained to relieve pore water pressures in the overburden as mine excavations progress.

Saturated alluvial deposits and uncemented siltstones and fine grained sandstones will readily erode and flow into excavations. This problem was encountered in drilling when the walls of holes collapsed and sloughed. Depth of excavation below the water table will be limited until these materials are unwatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of slopes.

Studies conducted at the Otter Creek Site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet width designed on the slope surface.

### Overburden Expansion

The degree to which the topography will be altered during surface mining depends upon many things - the most important being the (1) depth and thickness of coal being mined, (2) manner in which the spoil is returned to the pit, and (3) moisture content of the overburden. Overburden expands

as the materials are broken up during mining and an increase in void space occurs. The increase in volume (bulking) differs for various types of soil and rock. Soft sandstones and shales in the Wasatch and Fort Union Formations will likely expand between 25 and 30 percent. In some cases the surface of the replaced overburden may actually be higher in elevation after mining.

The following table shows the anticipated change in topography that would occur in the study area at selected drill holes if the Anderson, Dietz and Canyon Coalbeds are surface mined. This assumes that (1) stripping would occur to depths of 378 feet, (2) 100 percent of the coal would be removed, (3) overburden is replaced on a cut-by-cut basis, (4) spoils are smoothly graded, and (5) overburden expands 30 percent.

Table 2 - ELEVATION CHANGES DUE TO BULKING

| Drill Hole | Depth of Cut (1) | Thickness of Coal Removed (2) | Thickness of Replaced Overburden (3) | Difference in Elevation |
|---|---|---|---|---|
| 76-101 | 298 ft.± | 93 ft.± | 267 ft.± | -31 ft.± |
| -102 | 318 | 87 | 300 | -18 |
| -103 | 214 | 80 | 172 | -42 |
| -104(4) | 343 | 42 | 391 | +48 |
| -105 | 259 | 69 | 247 | -12 |
| -106 | 326 | 68 | 335 | +11 |
| -107 | 378 | 78 | 390 | +12 |
| -108 | 329 | 69 | 338 | + 9 |

(1) Base of Canyon Coalbed
(2) Includes 100 percent of Anderson, Dietz and Canyon Coalbeds
(3) Overburden x 1.3 (bulking factor) = Replaced Overburden
(4) Anderson Coalbed burned out

## Instability of the Postmining Landscape 1/

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains - they are: (1) areawide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include physical and chemical characteristics of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur.

Areawide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with the progression of time.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in more blocky and,

1/ Groenwold, G.H., and Rehm, B.W., 1980.

initially, more porous spoils than does coarse textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in mid-winter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks were concentrated by final, mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in mid-winter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

Piping appears to be a severe and long-term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoil.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

Piping, like the other instability problems, most commonly develops in areas contoured by dozers. Scraper contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

## Weathering Tests

Weathering tests were conducted on core samples from the White Tail Butte Study Area to determine which materials would break down sufficiently to allow for their use as topsoil in revegetation of surface-mined areas. Samples were selected for (1) freeze-thaw, (2) wet-dry, and (3) outdoor testing. The criteria developed for the testing is described as follows:

Freeze-Thaw Cycle

1. 8 hours at $75^{\circ}$ F., 100 percent relative humidity (wetting/thawing).

2. 16 hours (64 hours on weekends) at $0^{\circ}$ F. (freezing).

Wet-Dry Cycle

1. 8 hours at 75° F., 100 percent relative humidity (wetting).

2. 16 hours (64 hours on weekends) at 100° F., 10 percent relative humidity (drying).

Outdoor

The outdoor exposure test included subjecting the specimens to several snowstorms and a series of freeze-thaw cycles.

Shale samples tended to swell and break down readily under saturated conditions. Handling and placing these soils in a moist condition may be difficult due to their plastic characteristics. Sandstone and siltstone samples were more resistant to weathering than shales or silty shales. The freeze-thaw condition is more severe than the wet-dry in that it caused more rapid breakdown of most core samples.

## Seismic

The Yellowstone Park area is the most active seismic region within 300 miles of the White Tail Butte Study Area. The largest earthquake (7.1 Richter) recorded in this area occurred at Hebgen Lake, Montana, on August 17, 1959, a distance of 275 miles from the study site. Although considerable damage occurred near the epicenter, the quake was not readily noticed in the Powder River Basin. Forty-five earthquakes of moderate intensity (V to VII on the Modified Mercalli Intensity Scale) have occurred in Wyoming since 1894. Most of these have been centered in the northwestern part of the State.

The White Tail Butte Study Area is located in the Algermisson Seismic Risk Zone 1 in which minor damage could result to structures from Intensity V to VI (Modified Mercalli Intensity Scale) earthquake shocks. Earthquakes with intensities of V or greater that have occurred during historic times within 150 miles of the site are listed below:

| Date | Intensity (Modified Mercalli) | Distance From White Tail Butte | Located Near |
|---|---|---|---|
| June 25, 1894 | V | 135 miles | Casper, Wyo. |
| October 11, 1895 | V | 120 | Keystone, S.D. |
| November 14, 1897 | VI-VII | 135 | Casper, Wyo. |
| November 17, 1925 | V | 70 | Bighorn, Wyo. |
| November 16, 1928 | V | 120 | Custer, S.D. |
| March 24, 1964 | V | 140 | Hot Springs, S.D. |
| August 21, 1964 | V | 145 | Keeline, Wyo. |
| June 26, 1966 | VI | 125 | Rapid City, S.D. |

# COAL RESOURCES

## Introduction

This report is part of a program of study for the Bureau of Land Management aimed at determining the feasibility of surface mining and surface restoration of coal-bearing areas in the Western United States. Much of the report is offered as background needed in understanding the relatively short pertinent parts of the Energy Mineral Rehabilitation Inventory and Analysis study.

The basis for this report is core drilling and logging of seven holes in 1975 and eight holes in 1976, geologic mapping by the Water and Power Resources Service and the U.S. Geological Survey, and analytical data provided by the Bureau of Mines and Geological Survey laboratories. The coal and rock analyses are from the 1975 U.S. Geological Survey core drilling in the area. Maps prepared by G.J. Taucher, Water and Power Resources Service, were used as a basis for calculating the coal resource estimates presented in this report.

The coalbed nomenclature used here is consistent with the nomenclature used by Taucher. In other reports on this area, the U.S. Geological Survey considers that the bed here called Dietz is the upper split of the Canyon, or Canyon "A", and that the bed called Canyon is the lower split of the Canyon, or Canyon "B". The Dietz is not considered to be present here.

A section describing the origin, classification, rank, type, etc. of coal is included for reference in Appendix C.

The coal resources of the White Tail Butte Study Area are identified economic resources and all are categorized as a Reserve Base - coal more than 5 feet thick under less than 1000 feet of overburden (Table 4). In common with most coals of the United States, those occurring in this study area fall in the humic series.

## Coal Resources of the White Tail Butte Study Area

The ash, sulfur, and rank data for the White Tail Butte Study Area coals are:

| Coalbed | Ash Percent | Sulfur Percent | Apparent Rank | Hole No. |
|---|---|---|---|---|
| Anderson | 7.1 | 0.40 | Lignite 'A' | RM 2 & 3 |
| | | | Subbituminous 'C' | RM 1 & 4 |
| Dietz | 7.2 | 0.53 | Lignite 'A' | RM 2 |
| | | | Subbituminous 'C' | RM 1, 3 & 4 |
| Canyon | 6.8 | 0.53 | Subbituminous 'C' | |

Lacking precise data for the specific gravity and density in tons per acre-foot, a specific gravity of 1.29 and density of 1,750 tons per acre-foot were used in all resource calculations. These low figures were used because of the mixed lignite and low subbituminous C rank of the coals.

## Coal Analysis

As an aid in solution of problems of coal utilization, the following analytical determinations were made on all samples:

Bureau of Mines Coal Analysis Section:

1. Proximate analysis for percent moisture, volatile matter, fixed carbon, and ash: Ultimate analysis for percent hydrogen, carbon, nitrogen, oxygen, and sulfur; forms-of-sulfur, (inorganic and organic) and fusibility of ash.

Geological Survey Analytical laboratories:

1. Major composition of the ash of coal - percent ash, $SiO_2$, $Al_2O_3$, $Na_2O$, $K_2O$, CaO, MgO, $Fe_2O_3$, $P_2O_5$, Cl, MnO, $TiO_2$, and $SO_3$.

2. Trace element composition of coal.

   a. Individual quantitative determinations - As, Cd, Cu, F, Hg, Li, Pb, Sb, Se, Th, U, and Zn in parts per million.

   b. Semiquantitative spectrographic analysis - 20-30 elements detected by this method, reported in parts per million.

The sample data are from 3 coalbeds in 4 holes drilled by the USGS in 1975. Locations RM-2 through RM-4 are shown on Plate 7. RM-1 was drilled outside of the study area and is located about 2,150 feet northeast of Drill Hole 76-101. The breakdown by hole number and coalbed are:

| Hole No. | Number of Samples Tested | | |
|---|---|---|---|
| | Anderson | Dietz | Canyon |
| RM-1 | 10 | 6 | - |
| RM-2 | 4 | 4 | 3 |
| RM-3 | 15 | - | - |
| RM-4 | 7 | 7 | 7 |
| Subtotals | 36 | 17 | 10 |

These data are shown as weighted averages by hole number and the coalbed on Tables 5, 6 and 7. Table 8 compares various oxides and element data of the White Tail Butte Study Area with composite values of other subbituminous coals of the Powder River Basin.

Table 9 shows the range of and average element content on the whole-coal basis of those constituents commonly regarded as being of importance from the standpoint of coal utilization. Some of the elements, such as mercury

Estimated identified coal resources of 3 coal beds within the EMRIA White Tail Butte Study Area, that is shown on Plate 2 .

[In thousands of short tons. To convert to metric tons multiply by 0.90718. To convert feet to meters, multiply by 0.305.]

| OVERBURDEN THICKNESS (in ft) | 0-200 | | | Over 200 | | | |
|---|---|---|---|---|---|---|---|
| Section[1/] | Measured | Indicated | Subtotal | Measured | Indicated | Subtotal | Total |
| | | | Anderson coal bed | | | | |
| Sec. 30P, T. 56 N., R. 72 W. | 3,833 | 2,153 | 5,986 | 0 | 0 | 0 | 5,986 |
| Sec. 31P, T. 56 N., R. 72 W. | 5,198 | 9,674 | 14,872 | 0 | 6 | 6 | 14,878 |
| Sec. 32, T. 56 N., R. 72 W. | 11,739 | 23,129 | 34,868 | 1,197 | 260 | 1,457 | 36,325 |
| Sec. 24P, T. 56 N., R. 73 W. | 3,015 | 4,608 | 7,623 | 0 | 0 | 0 | 7,623 |
| Sec. 25P, T. 56 N., R. 73 W. | 19,939 | 11,176 | 31,115 | 0 | 0 | 0 | 31,115 |
| Total for Anderson coal bed | 43,724 | 50,740 | 94,464 | 1,197 | 266 | 1,463 | 95,927 |
| | | | Dietz coal bed | | | | |
| Sec. 30P, T. 56 N., R. 72 W. | 4,456 | 3,125 | 7,581 | 2,128 | 4,190 | 6,318 | 13,899 |
| Sec. 31P, T. 56 N., R. 72 W. | 4,822 | 1,629 | 6,451 | 7,315 | 2,062 | 9,377 | 15,828 |
| Sec. 32, T. 56 N., R. 72 W. | 11,375 | 8,488 | 19,863 | 6,038 | 1,881 | 7,919 | 27,782 |
| Sec. 24P, T. 56 N., R. 73 W. | 297 | 268 | 565 | 2,321 | 1,309 | 3,630 | 4,195 |
| Sec. 25P, T. 56 N., R. 73 W. | 725 | 0 | 725 | 9,009 | 8,789 | 17,798 | 18,523 |
| Total for Dietz coal bed | 21,675 | 13,510 | 35,185 | 26,811 | 18,231 | 45,042 | 80,227 |
| | | | Canyon coal bed | | | | |
| Sec. 30P, T. 56 N., R. 72 W. | 2,940 | 5,292 | 8,232 | 6,762 | 5,488 | 12,250 | 20,482 |
| Sec. 31P, T. 56 N., R. 72 W. | 4,700 | 420 | 5,120 | 10,630 | 4,242 | 14,872 | 19,992 |
| Sec. 32, T. 56 N., R. 72 W. | 4,279 | 7,144 | 11,423 | 13,830 | 3,640 | 17,470 | 28,893 |
| Sec. 24P, T. 56 N., R. 73 W. | Neg.[2/] | 0 | 0 | 3,388 | 1,694 | 5,082 | 5,082 |
| Sec. 25P, T. 56 N., R. 73 W. | Neg. | 0 | 0 | 11,400 | 10,740 | 22,140 | 22,140 |
| Total for Canyon coal bed | 11,919 | 12,856 | 24,775 | 46,010 | 25,804 | 71,814 | 96,589 |
| GRAND TOTAL | | | 154,424 | | | 118,319 | 272,743 |

1/ "P" means partial section.

2/ "Neg." means negligible.

Table 4
Sheet 1 of 2

Estimated identified coal resources of 3 coal beds in the White Tail Butte Study Area and surrounding area that is shown on Plate 2. (In thousands of short tons. To convert to metric tons, multiply by 0.90718. To convert feet to meters, multiply by 0.305)

| OVERBURDEN THICKNESS (in ft) | 0-200 | | | | Over 200 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Section[1/] | Measured | Indicated | Inferred | Subtotal | Measured | Indicated | Inferred | Subtotal | Total |
| **Anderson coal bed** | | | | | | | | | |
| Sec. 4P, T. 55 N., R. 72 W. | 0 | 1,813 | 0 | 1,813 | 0 | 0 | 0 | 0 | 1,813 |
| Sec. 5P, T. 55 N., R. 72 W. | 0 | 2,060 | 0 | 2,060 | 0 | 0 | 0 | 0 | 2,060 |
| Sec. 28P, T. 56 N., R. 72 W. | 0 | 809 | 0 | 809 | 0 | 0 | 0 | 0 | 809 |
| Sec. 29, T. 56 N., R. 72 W. | 0 | 8,691 | 0 | 8,691 | 0 | 0 | 0 | 0 | 8,691 |
| Sec. 30, T. 56 N., R. 72 W. | 3,833 | 2,153 | 0 | 5,986 | 0 | 0 | 0 | 0 | 5,986 |
| Sec. 31, T. 56 N., R. 72 W. | 3,198 | 9,474 | 0 | 12,672 | 0 | 6 | 0 | 6 | 12,678 |
| Sec. 32, T. 56 N., R. 72 W. | 11,739 | 23,129 | 0 | 34,868 | 1,197 | 260 | 0 | 1,457 | 36,325 |
| Sec. 33P, T. 56 N., R. 72 W. | 3,892 | 2,457 | 0 | 6,349 | 0 | 0 | 0 | 0 | 6,349 |
| Sec. 23P, T. 56 N., R. 73 W. | 0 | 1,871 | 1,633 | 3,504 | 0 | 0 | 0 | 0 | 3,504 |
| Sec. 24P, T. 56 N., R. 73 W. | 5,527 | 11,408 | 0 | 16,935 | 0 | 0 | 0 | 0 | 16,935 |
| Sec. 25, T. 56 N., R. 73 W. | 19,939 | 11,176 | 0 | 31,115 | 0 | 0 | 0 | 0 | 31,115 |
| Sec. 26P, T. 56 N., R. 73 W. | 2,482 | 2,670 | 0 | 5,152 | 0 | 0 | 0 | 0 | 5,152 |
| Sec. 35P, T. 56 N., R. 73 W. | 0 | 3,694 | 1,839 | 5,733 | 0 | 0 | 0 | 0 | 5,733 |
| Sec. 36, T. 56 N., R. 73 W. | 648 | 4,326 | 14,839 | 19,813 | 0 | 0 | 0 | 0 | 19,813 |
| Total for Anderson coal bed | 51,258 | 86,131 | 24,039 | 161,428 | 1,197 | 266 | 0 | 1,457 | 162,891 |
| **Dietz coal bed** | | | | | | | | | |
| Sec. 4P, T. 55 N., R. 72 W. | 0 | 932 | 0 | 982 | 0 | 270 | 0 | 270 | 1,252 |
| Sec. 5P, T. 55 N., R. 72 W. | 0 | 5,812 | 0 | 5,812 | 0 | 359 | 0 | 359 | 6,171 |
| Sec. 6P, T. 55 N., R. 72 W. | 0 | 2,564 | 3,119 | 5,683 | 0 | 0 | 0 | 0 | 5,683 |
| Sec. 1P, T. 55 N., R. 73 W. | 0 | 2,423 | 613 | 3,036 | 2,484 | 162 | 0 | 2,646 | 5,682 |
| Sec. 19P, T. 56 N., R. 72 W. | 0 | 2,906 | 1,024 | 3,930 | 0 | 0 | 0 | 0 | 3,930 |
| Sec. 28P, T. 56 N., R. 72 W. | 0 | 696 | 0 | 696 | 0 | 0 | 0 | 0 | 696 |
| Sec. 29, T. 56 N., R. 72 W. | 0 | 15,112 | 2,894 | 18,006 | 0 | 0 | 0 | 0 | 18,006 |
| Sec. 30, T. 56 N., R. 72 W. | 3,026 | 8,379 | 0 | 11,405 | 2,660 | 1,995 | 0 | 4,655 | 16,060 |
| Sec. 31, T. 56 N., R. 72 W. | 3,358 | 6,218 | 0 | 9,576 | 6,517 | 4,256 | 0 | 10,773 | 20,349 |
| Sec. 32, T. 56 N., R. 72 W. | 11,375 | 8,488 | 0 | 19,863 | 6,038 | 1,881 | 0 | 7,919 | 27,782 |
| Sec. 33P, T. 56 N., R. 72 W. | 2,931 | 1,050 | 0 | 3,981 | 68 | 613 | 0 | 701 | 4,682 |
| Sec. 23P, T. 56 N., R. 73 W. | 0 | 0 | 0 | 0 | 0 | 1,483 | 565 | 2,353 | 2,353 |
| Sec. 24P, T. 56 N., R. 73 W. | 1,523 | 2,797 | 0 | 4,320 | 3,154 | 5,534 | 0 | 8,688 | 13,008 |
| Sec. 25, T. 56 N., R. 73 W. | 599 | 0 | 0 | 599 | 11,655 | 7,907 | 0 | 19,562 | 20,161 |
| Sec. 35P, T. 56 N., R. 73 W. | 0 | 0 | 0 | 0 | 0 | 2,072 | 0 | 2,072 | 2,072 |
| Sec. 36, T. 56 N., R. 73 W. | 736 | 5,088 | 0 | 5,824 | 4,452 | 5,684 | 0 | 10,136 | 15,960 |
| Total for Dietz coal bed | 23,568 | 62,495 | 7,650 | 93,713 | 37,048 | 32,221 | 565 | 69,834 | 163,547 |
| **Canyon coal bed** | | | | | | | | | |
| Sec. 4P, T. 55 N., R. 72 W. | 0 | 378 | 0 | 378 | 0 | 1,229 | 0 | 1,229 | 1,607 |
| Sec. 5P, T. 55 N., R. 72 W. | 0 | 11,375 | 0 | 11,375 | 0 | 865 | 0 | 865 | 12,240 |
| Sec. 6P, T. 55 N., R. 72 W. | 319 | 8,691 | 2,002 | 11,012 | 0 | 0 | 0 | 0 | 11,012 |
| Sec. 1P, T. 55 N., R. 73 W. | 0 | 2,002 | 1,617 | 3,619 | 2,734 | 1,732 | 0 | 4,466 | 8,085 |
| Sec. 19P, T. 56 N., R. 72 W. | 0 | 2,242 | 6,578 | 8,820 | 0 | 673 | 0 | 673 | 9,493 |
| Sec. 20P, T. 56 N., R. 72 W. | 0 | 0 | 10,217 | 10,217 | 0 | 0 | 0 | 0 | 10,217 |
| Sec. 21P, T. 56 N., R. 72 W. | 0 | 0 | 635 | 635 | 0 | 0 | 0 | 0 | 635 |
| Sec. 28P, T. 56 N., R. 72 W. | 0 | 1,360 | 2,215 | 3,575 | 0 | 0 | 0 | 0 | 3,575 |
| Sec. 29, T. 56 N., R. 72 W. | 0 | 15,545 | 4,263 | 19,808 | 0 | 1,580 | 3,712 | 5,292 | 25,100 |
| Sec. 30, T. 56 N., R. 72 W. | 1,029 | 9,702 | 0 | 10,731 | 4,520 | 6,799 | 0 | 11,319 | 22,050 |
| Sec. 31, T. 56 N., R. 72 W. | 4,368 | 3,780 | 0 | 8,148 | 8,988 | 8,400 | 0 | 17,388 | 25,536 |
| Sec. 32, T. 56 N., R. 72 W. | 4,279 | 7,144 | 0 | 11,423 | 13,830 | 3,640 | 0 | 17,470 | 28,893 |
| Sec. 33P, T. 56 N., R. 72 W. | 588 | 1,078 | 0 | 1,666 | 3,136 | 392 | 0 | 3,528 | 5,194 |
| Sec. 23P, T. 56 N., R. 73 W. | 0 | 0 | 0 | 0 | 0 | 2,194 | 0 | 2,194 | 2,194 |
| Sec. 24P, T. 56 N., R. 73 W. | 270 | 4,197 | 0 | 4,467 | 4,235 | 9,240 | 0 | 13,475 | 17,942 |
| Sec. 25, T. 56 N., R. 73 W. | 0 | 0 | 0 | 0 | 12,051 | 12,128 | 0 | 24,179 | 24,179 |
| Sec. 26P, T. 56 N., R. 73 W. | 0 | 0 | 0 | 0 | 1,775 | 1,411 | 0 | 3,186 | 3,186 |
| Sec. 35P, T. 56 N., R. 73 W. | 0 | 0 | 0 | 0 | 0 | 3,179 | 0 | 3,179 | 3,179 |
| Sec. 36, T. 56 N., R. 73 W. | 0 | 3,535 | 0 | 3,535 | 5,635 | 13,370 | 0 | 19,005 | 22,540 |
| Total for Canyon coal bed | 10,853 | 71,029 | 27,527 | 109,409 | 56,904 | 66,632 | 3,712 | 127,448 | 236,857 |
| GRAND TOTAL | 85,679 | 219,655 | 59,216 | 364,550 | 95,149 | 99,319 | 4,277 | 198,739 | 563,295 |

Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 3 coal beds from 4 drill holes, EMRIA White Tail Butte Study Site, Campbell County, Wyoming

[All analyses except heat of combustion, free-swelling index, and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa. °C = (°F-32) 5/9; Kcal/kg = (Btu/lb) All figures shown are weighted average values from 36 samples of the Anderson, 17 of the Dietz and 10 of the Canyon coal beds.]

| HOLE AND COAL BED | FORM OF ANALYSIS | PROXIMATE ANALYSIS | | | | ULTIMATE ANALYSIS | | | | | BTU (per lb) | FORMS OF SULFUR | | | FUSIBILITY OF ASH (°F) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MOISTURE | VOLATILE MATTER | FIXED CARBON | ASH | HYDROGEN | CARBON | NITROGEN | OXYGEN | SULFUR | | SULFATE | PYRITIC | ORGANIC | INITIAL DEFORMATION | SOFTENING | FLUID |
| RM-1 Anderson | 1 | 32.0 | 29.9 | 32.4 | 5.7 | 6.7 | 44.8 | 0.6 | 41.7 | 0.4 | 7563 | 0.01 | 0.02 | 0.39 | 2280 | 2310 | 2340 |
| | 2 | ---- | 44.0 | 47.7 | 8.4 | 4.6 | 65.9 | .9 | 19.5 | .6 | 11120 | .02 | .03 | .57 | | | |
| | 3 | ---- | 48.0 | 52.0 | --- | 5.1 | 71.9 | 1.0 | 21.3 | .7 | 12140 | .02 | .04 | .62 | | | |
| | 4 | 12.6 | 38.5 | 41.7 | 7.3 | 5.5 | 57.6 | .8 | 28.8 | .5 | 9728 | ---- | ---- | ---- | | | |
| RM-2 Anderson | 1 | 32.1 | 29.5 | 29.6 | 8.8 | 6.7 | 42.6 | 0.6 | 40.9 | 0.4 | 7206 | 0.02 | 0.02 | 0.35 | 2180 | 2210 | 2240 |
| | 2 | ---- | 43.5 | 43.6 | 13.0 | 4.6 | 62.7 | .9 | 18.2 | .6 | 10620 | .03 | .03 | .52 | | | |
| | 3 | ---- | 49.9 | 50.1 | ---- | 5.3 | 72.1 | 1.0 | 20.9 | .7 | 12200 | ---- | ---- | ---- | | | |
| | 4 | 10.9 | 36.6 | 36.8 | 11.0 | 5.6 | 52.9 | .7 | 29.3 | .5 | 8959 | ---- | ---- | ---- | | | |
| RM-3 Anderson | 1 | 31.3 | 31.1 | 30.7 | 6.8 | 6.6 | 44.4 | 0.8 | 41.1 | 0.4 | 7491 | 0.01 | 0.01 | 0.38 | 2270 | 2310 | 2350 |
| | 2 | ---- | 45.3 | 44.8 | 9.9 | 4.5 | 64.6 | 1.1 | 19.3 | .6 | 10910 | .01 | .02 | .55 | | | |
| | 3 | ---- | 50.3 | 49.7 | --- | 5.0 | 71.7 | 1.2 | 21.4 | .6 | 12110 | .02 | .02 | .61 | | | |
| | 4 | 13.2 | 39.3 | 38.9 | 8.5 | 5.4 | 56.0 | 1.0 | 28.6 | .5 | 9466 | ---- | ---- | ---- | | | |
| RM-4 Anderson | 1 | 31.3 | 29.5 | 32.1 | 7.1 | 6.6 | 44.2 | 0.7 | 39.6 | 0.4 | 7617 | 0.01 | 0.01 | 0.38 | 2340 | 2370 | 2400 |
| | 2 | ---- | 43.0 | 46.8 | 10.3 | 4.5 | 64.3 | 1.0 | 17.2 | .6 | 11030 | .01 | .02 | .55 | | | |
| | 3 | ---- | 47.9 | 52.1 | ---- | 5.0 | 71.7 | 1.2 | 19.2 | .7 | 12350 | .02 | .02 | .61 | | | |
| | 4 | 12.3 | 37.8 | 41.2 | 8.8 | 5.4 | 57.4 | .9 | 27.0 | .5 | 9747 | ---- | ---- | ---- | | | |
| Average value Anderson coal bed | 1 | 31.7 | 30.0 | 31.2 | 7.1 | 6.7 | 44.0 | 0.7 | 40.8 | 0.4 | 7469 | 0.01 | 0.02 | 0.38 | 2270 | 2300 | 2330 |
| | 2 | ---- | 43.9 | 45.7 | 10.4 | 4.6 | 64.4 | 1.0 | 18.6 | 0.6 | 10930 | .02 | .03 | .55 | | | |
| | 3 | ---- | 49.0 | 51.0 | ---- | 5.1 | 71.9 | 1.1 | 20.7 | 0.7 | 12200 | .03 | .03 | .61 | | | |
| | 4 | 12.3 | 38.1 | 39.7 | 8.9 | 5.5 | 56.0 | 0.9 | 28.4 | 0.5 | 9475 | ---- | ---- | ---- | | | |

Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 3 coal beds from 4 drill holes, EYRIA White Tail Butte Study Site, Campbell County, Wyoming--Continued

| HOLE AND COAL BED | FORM OF ANALYSIS | PROXIMATE ANALYSIS | | | | ULTIMATE ANALYSIS | | | | | BTU (per lb) | FORMS OF SULFUR | | | FUSIBILITY OF ASH (°F) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MOISTURE | VOLATILE MATTER | FIXED CARBON | ASH | HYDROGEN | CARBON | NITROGEN | OXYGEN | SULFUR | | SULFATE | PYRITIC | ORGANIC | INITIAL DEFORMATION | SOFTENING | FLUID |
| RM-1 Dietz | 1 | 32.6 | 29.2 | 32.4 | 5.7 | 6.7 | 44.8 | 0.6 | 41.7 | 0.5 | 7507 | 0.01 | 0.02 | 0.46 | 2300 | 2330 | 2360 |
| | 2 | ---- | 43.4 | 48.1 | 8.5 | 4.5 | 66.5 | .9 | 18.8 | .7 | 11140 | .01 | .03 | .69 | | | |
| | 3 | ---- | 47.4 | 52.6 | --- | 4.9 | 72.7 | 1.0 | 20.6 | .8 | 12180 | .02 | .03 | .75 | | | |
| | 4 | 13.3 | 37.6 | 41.6 | 7.4 | 5.4 | 57.6 | .8 | 28.1 | .6 | 9657 | ---- | ---- | ---- | | | |
| RM-2 Dietz | 1 | 32.8 | 26.4 | 30.0 | 10.8 | 6.5 | 40.4 | 0.5 | 41.2 | 0.6 | 6778 | 0.05 | 0.14 | 0.38 | 2390 | 2440 | 2520 |
| | 2 | ---- | 39.2 | 44.7 | 16.1 | 4.3 | 60.1 | .7 | 17.9 | .8 | 10080 | .08 | .21 | .56 | | | |
| | 3 | ---- | 46.7 | 53.3 | ---- | 5.1 | 71.7 | .9 | 21.3 | 1.0 | 12120 | .09 | .25 | .67 | | | |
| | 4 | 16.4 | 32.7 | 37.3 | 13.6 | 5.4 | 50.2 | .7 | 29.5 | .7 | 8413 | ---- | ---- | ---- | | | |
| RM-4 Dietz | 1 | 33.8 | 27.7 | 33.5 | 5.0 | 6.7 | 44.6 | 0.8 | 42.4 | 0.5 | 7457 | 0.02 | 0.06 | 0.44 | 2300 | 2330 | 2360 |
| | 2 | ---- | 41.9 | 50.6 | 7.6 | 4.5 | 67.3 | 1.1 | 18.8 | .8 | 11260 | .03 | .09 | .67 | | | |
| | 3 | ---- | 45.3 | 54.7 | --- | 4.9 | 72.8 | 1.2 | 20.3 | .8 | 12180 | .04 | .10 | .72 | | | |
| | 4 | 10.8 | 33.1 | 45.2 | 6.7 | 5.2 | 60.0 | 1.0 | 26.4 | .7 | 10041 | ---- | ---- | ---- | | | |
| Average value - Dietz coal bed: | 1 | 33.1 | 27.8 | 32.0 | 7.2 | 6.6 | 43.3 | 0.6 | 41.8 | 0.5 | 7247 | 0.03 | 0.07 | 0.43 | 2330 | 2370 | 2410 |
| | 2 | ---- | 41.5 | 47.8 | 10.7 | 4.4 | 64.6 | .9 | 18.5 | .8 | 10830 | .04 | .11 | .64 | | | |
| | 3 | ---- | 46.5 | 53.5 | ---- | 5.0 | 72.4 | 1.0 | 20.7 | .9 | 12160 | .05 | .13 | .71 | | | |
| | 4 | 13.5 | 34.5 | 41.4 | 9.2 | 5.3 | 55.9 | .8 | 28.0 | .7 | 9370 | ---- | ---- | ---- | | | |

Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 3 coal beds from 4 drill holes, ERDA White Tail Butte Study Site, Campbell County, Wyoming--Continued

| HOLE AND COAL BED | FORM OF ANALYSIS | PROXIMATE ANALYSIS | | | | ULTIMATE ANALYSIS | | | | | BTU (per lb) | FORMS OF SULFUR | | | FUSIBILITY OF ASH (°F) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MOISTURE | VOLATILE MATTER | FIXED CARBON | ASH | HYDROGEN | CARBON | NITROGEN | OXYGEN | SULFUR | | SULFATE | PYRITIC | ORGANIC | INITIAL DEFORMATION | SOFTENING | FLUID |
| RM-2 Canyon | | | | | | | | | | | | | | | | | |
| | 1 | 34.1 | 27.9 | 33.0 | 5.0 | 6.8 | 44.7 | 0.6 | 42.6 | 0.3 | 7458 | 0.02 | 0.02 | 0.32 | 2265 | 2325 | 2350 |
| | 2 | ---- | 42.3 | 50.1 | 7.6 | 4.6 | 67.8 | .9 | 18.7 | .5 | 11310 | .03 | .03 | .48 | | | |
| | 3 | ---- | 45.8 | 54.2 | --- | 5.0 | 73.3 | 1.0 | 20.2 | .5 | 12240 | .04 | .03 | .52 | | | |
| | 4 | 14.8 | 36.0 | 42.6 | 6.5 | 5.5 | 57.8 | .7 | 29.0 | .4 | 9652 | ---- | ---- | ---- | | | |
| RM-4 Canyon | | | | | | | | | | | | | | | | | |
| | 1 | 34.7 | 28.0 | 33.0 | 4.3 | 6.8 | 44.7 | 0.7 | 43.3 | 0.2 | 7528 | 0.01 | 0.01 | 0.24 | 2340 | 2370 | 2400 |
| | 2 | ---- | 42.9 | 50.6 | 6.6 | 4.5 | 68.4 | 1.0 | 19.0 | .4 | 11530 | .02 | .02 | .37 | | | |
| | 3 | ---- | 45.9 | 54.1 | --- | 4.8 | 73.3 | 1.1 | 20.4 | .4 | 12340 | .02 | .02 | .40 | | | |
| | 4 | 11.0 | 38.2 | 44.9 | 5.9 | 5.3 | 60.9 | 1.0 | 26.6 | .3 | 10263 | ---- | ---- | ---- | | | |
| Average value - Canyon coal bed | | | | | | | | | | | | | | | | | |
| | 1 | 34.4 | 28.0 | 33.0 | 4.7 | 6.8 | 44.7 | 0.7 | 43.0 | 0.3 | 7493 | 0.02 | 0.02 | 0.28 | 2300 | 2350 | 2375 |
| | 2 | ---- | 42.6 | 50.4 | 7.1 | 4.6 | 68.1 | 1.0 | 18.9 | .5 | 11420 | .03 | .03 | .44 | | | |
| | 3 | ---- | 45.9 | 54.2 | --- | 4.9 | 73.3 | 1.1 | 20.3 | .5 | 12290 | .03 | .03 | .46 | | | |
| | 4 | 12.9 | 37.1 | 43.8 | 6.2 | 5.4 | 59.4 | .9 | 27.8 | .4 | 9958 | ---- | ---- | ---- | | | |

Table 6
Sheet 1 of 2

Major and minor oxide and trace element composition of the laboratory ash of 3 coal beds from 4 drill holes, EMRIA White Tail Study Site, Campbell County, Wyoming

[Values in percent or parts per million. Coal ashed at 525°. N, not detected; B, not determined; --- less than detection limits. S after element title indicates determinations by semiquantative emission spectrography. The spectrographic results are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc., but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level. All figures shown are weighted average values from 36 samples of the Anderson, 17 of the Dietz and 10 of the Canyon coalbeds.]

| Hole No. | Coal bed | Ash % | SiO2 % | Al2O3 % | CaO % | MgO % | Na2O % | K2O % | Fe2O3 % | MnO % | TiO2 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RM-1 | Anderson | 8.9 | 22 | 13 | 28 | 5.66 | 2.34 | 0.45 | 5.2 | 0.017 | 0.82 |
| | Dietz | 8.0 | 21 | 12 | 25 | 6.39 | 2.25 | .51 | 4.7 | .021 | .71 |
| RM-2 | Anderson | 10.4 | 32 | 13 | 17 | 5.05 | 1.99 | .48 | 2.9 | ---- | 1.1 |
| | Dietz | 14.1 | 30 | 14 | 14 | 5.09 | 1.86 | .46 | 3.9 | ---- | .80 |
| | Canyon | 7.3 | 15 | 8.1 | 18 | 6.62 | 2.08 | .20 | 9.4 | ---- | .39 |
| RM-3 | Anderson | 10.1 | 22 | 13 | 29 | 6.26 | 1.98 | .39 | 4.7 | .094 | .82 |
| RM-4 | Anderson | 8.5 | 19 | 14 | 19 | 7.17 | 2.87 | .30 | 4.2 | <.05 | 1.3 |
| | Dietz | 7.3 | 19 | 11 | 19 | 6.96 | 3.20 | .26 | 6.8 | ---- | 1.1 |
| | Canyon | 7.0 | 19 | 12 | 19 | 7.05 | 3.09 | .31 | 9.3 | ---- | .69 |

| Hole No. | Coal bed | P2O5 % | SO3 % | Cu ppm | Li ppm | Pb ppm | Zn ppm | B ppm-S | Ba ppm-S | Be ppm-S | Co ppm-S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RM-1 | Anderson | ---- | 4.7 | 135 | -- | -- | 74 | 500 | 5,000 | --- | 15 |
| | Dietz | .95 | 6.5 | 120 | -- | -- | 86 | 500 | 3,000 | --- | 15 |
| RM-2 | Anderson | ---- | 9.5 | 152 | 26 | -- | 77 | 700 | 7,000 | --- | 15 |
| | Dietz | ---- | 12 | 147 | -- | -- | 120 | 700 | 5,000 | --- | 15 |
| | Canyon | ---- | 13 | 53 | -- | --- | 31 | 1,000 | 10,000 | --- | -- |
| RM-3 | Anderson | 2.6 | 13 | 147 | -- | -- | 55 | 700 | 7,000 | --- | 15 |
| RM-4 | Anderson | 0.5 | 13 | 155 | 26 | 34 | 137 | 700 | 5,000 | --- | 15 |
| | Dietz | ---- | 18 | 115 | -- | -- | 158 | 700 | 5,000 | --- | 20 |
| | Canyon | ---- | 11 | 70 | -- | -- | 169 | 700 | 5,000 | --- | -- |

Major and minor oxide and trace element composition of the laboratory ash of 3 coal beds from 4 drill holes, EMRIA White Tail Study Site, Campbell County, Wyoming--Continued

| Hole No. | Coal bed | Cr ppm-S | Ga ppm-S | Mo ppm-S | Nb ppm-S | Ni ppm-S | Sc ppm-S | Sr ppm-S | V ppm-S | Y ppm-S | Yb ppm-S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RM-1 | Anderson | 70 | 20 | -- | -- | 30 | 20 | 1,500 | 200 | 50 | 5 |
| | Dietz | 70 | 20 | 10 | -- | 30 | 20 | 1,500 | 200 | 70 | 5 |
| RM-2 | Anderson | 70 | 50 | 7 | -- | 20 | 20 | 1,500 | 200 | 50 | 7 |
| | Dietz | 100 | 30 | 15 | -- | 50 | 20 | 2,000 | 200 | 50 | 7 |
| | Canyon | 50 | 20 | 7 | -- | 50 | -- | 2,000 | 100 | 50 | 7 |
| RM-3 | Anderson | 70 | 30 | -- | -- | 30 | 20 | 1,500 | 200 | 30 | 5 |
| RM-4 | Anderson | 50 | 20 | -- | -- | 30 | 20 | 700 | 200 | 30 | 3 |
| | Dietz | 70 | 20 | 15 | -- | 50 | 20 | 1,000 | 200 | 70 | 7 |
| | Canyon | 30 | 15 | 7 | -- | 50 | -- | 700 | 100 | -- | - |

| Hole No. | Coal bed | Zr ppm-S |
|---|---|---|
| RM-1 | Anderson | 150 |
| | Dietz | 150 |
| RM-2 | Anderson | 150 |
| | Dietz | 150 |
| | Canyon | 100 |
| RM-3 | Anderson | 150 |
| RM-4 | Anderson | 150 |
| | Dietz | 200 |
| | Canyon | 150 |

Table 6
Sheet 2 of 2

Major, minor, and trace element composition of 3 coalbeds from 4 drill holes, EMRIA White Tail Butte Study Site, Campbell County, Wyoming

[Values in percent or parts per million. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal; all other values calculated from analyses of ash. S means analysis by emission spectrography; N, not detected; B, not determined, --- not detected or below detection limits. All figures shown are weighted average values from 36 samples of the Anderson, 17 of the Dietz, and 10 of the Canyon coal beds]

| Hole No. | Coal bed | Si % | Al % | Ca % | Mg % | Na % | K % | Fe % | Mn ppm | Ti % | P ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RM-1 | Anderson | 1.2 | 0.74 | 1.5 | 0.259 | 0.126 | 0.040 | 0.30 | 9.7 | 0.047 | ---- |
| | Dietz | .92 | .58 | 1.3 | .276 | .121 | .039 | .24 | 11 | .038 | 390 |
| RM-2 | Anderson | 1.7 | .84 | 1.1 | .284 | .136 | .050 | .20 | ---- | .064 | ---- |
| | Dietz | 2.7 | 1.3 | .90 | .285 | .122 | .078 | .31 | ---- | .077 | ---- |
| | Canyon | .50 | .31 | .93 | .289 | .112 | .012 | .47 | ---- | .017 | ---- |
| RM-3 | Anderson | 1.4 | .82 | 1.7 | .326 | .120 | .048 | .31 | 61 | .054 | 1000 |
| RM-4 | Anderson | .92 | .70 | 1.0 | .333 | .161 | .029 | .24 | ---- | .063 | ---- |
| | Dietz | .72 | .41 | .92 | .285 | .159 | .017 | .36 | ---- | .052 | ---- |
| | Canyon | .74 | .50 | .85 | .274 | .145 | .021 | .41 | ---- | .032 | ---- |

| Hole No. | Coal bed | As ppm | Cu ppm | F ppm | Hg ppm | Li ppm | Pb ppm | Sb ppm | Se ppm | U ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RM-1 | Anderson | - | 12.0 | --- | 0.13 | --- | --- | --- | 0.9 | 1.0 | 10.3 |
| | Dietz | 2 | 10.4 | 66 | .09 | --- | --- | --- | .8 | ---- | 8.8 |
| RM-2 | Anderson | 1 | 15.1 | 101 | .10 | 3.2 | --- | --- | .9 | ---- | 9.5 |
| | Dietz | 2 | 21.5 | 76 | .09 | --- | --- | --- | 1.1 | ---- | 24.5 |
| | Canyon | 1 | 3.9 | 48 | .05 | --- | --- | --- | .4 | ---- | 2.3 |
| RM-3 | Anderson | - | 15.6 | -- | .11 | --- | --- | .3 | 1.3 | --- | 6.5 |
| RM-4 | Anderson | 1 | 12.8 | 48 | .10 | --- | 2.9 | --- | 1.2 | .6 | 13.6 |
| | Dietz | 2 | 8.2 | 55 | .07 | --- | --- | --- | .7 | .6 | 12.1 |
| | Canyon | 2 | 5.7 | 46 | ---- | --- | --- | --- | .8 | ---- | 13.4 |

Major, minor, and trace element composition of 3 coalbeds from 4 drill holes, EMRIA White Tail Butte Study Site, Campbell County, Wyoming--Continued

| Hole No. | Coal bed | B ppm-S | Ba ppm-S | Be ppm-S | Co ppm-S | Cr ppm-S | Ga ppm-S | Mo ppm-S | Nb ppm-S | Ni ppm-S | Sc ppm-S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RM-1 | Anderson | 30 | 500 | ---- | 1.5 | 10 | 2 | --- | --- | 5 | 3 |
| | Dietz | 50 | 200 | ---- | 1.0 | 7 | 2 | 1 | --- | 3 | 2 |
| RM-2 | Anderson | 70 | 700 | ---- | 1.5 | 10 | 5 | 1 | --- | 3 | 3 |
| | Dietz | 70 | 500 | ---- | 2.0 | 20 | 7 | 3 | --- | 7 | 3 |
| | Canyon | 70 | 700 | ---- | --- | 2 | 1.5 | .5 | --- | 2 | --- |
| RM-3 | Anderson | 50 | 700 | ---- | 1.5 | 2 | 3 | --- | --- | 3 | 2 |
| RM-4 | Anderson | 50 | 300 | ---- | 1.5 | 5 | 2 | --- | --- | 2 | 1.5 |
| | Dietz | 50 | 500 | ---- | 1.5 | 5 | 2 | 1 | --- | 5 | 1.5 |
| | Canyon | 50 | 300 | ---- | --- | 3 | 1 | .5 | --- | 3 | --- |

| Hole No. | Coal bed | Sr ppm-S | V ppm-S | Y ppm-S | Yb ppm-S | Zr ppm-S |
|---|---|---|---|---|---|---|
| RM-1 | Anderson | 100 | 20 | 5 | .5 | 15 |
| | Dietz | 100 | 15 | 7 | .5 | 10 |
| RM-2 | Anderson | 100 | 30 | 5 | .7 | 15 |
| | Dietz | 300 | 50 | 10 | 1.0 | 20 |
| | Canyon | 150 | 7 | 3 | .5 | 7 |
| RM-3 | Anderson | 150 | 20 | 5 | .5 | 20 |
| RM-4 | Anderson | 50 | 20 | 3 | .3 | 15 |
| | Dietz | 70 | 15 | 7 | .5 | 15 |
| | Canyon | 50 | 10 | - | --- | 10 |

Table 8 --Comparison of the average content of selected trace elements and oxides in the Anderson, Dietz, and Canyon coal beds with average abundance in coals of the Powder River Region.

| | Anderson | Dietz | Canyon | Powder River Region (410 samples)[1/] |
|---|---|---|---|---|
| | | in percent | | |
| $SiO_2$ (in ash) | 23.8 | 23.3 | 17.0 | 30 |
| $Na_2O$ " " | 2.3 | 2.4 | 2.7 | 1.9 |
| CaO " " | 23.0 | 19.0 | 19.0 | 18 |
| MgO " " | 6.0 | 9.1 | 6.7 | 4.0 |
| | | in parts per million | | |
| As (whole coal) | 1.5 | 2 | 2 | 3 |
| B " " | 50 | 60 | 60 | 70 |
| Ba " " | 550 | 400 | 500 | 300 |
| Hg " " | 0.11 | 0.08 | 0.04 | 0.11 |
| Pb " " | 2.9 | L | L | 6.4 |
| Se " " | 1.1 | 0.9 | 0.6 | 1.0 |
| U " " | 0.9 | 1.3 | 0.6 | 0.9 |
| Zn " " | 10.0 | 15.1 | 7.9 | 20 |

1/ Hatch, J. R. and Swanson, V. E., 1976, Trace elements in Rocky Mountain and Northern Great Plains coal, Table 6a and 6b, Presented at the Rocky Mountain Coal Symposium, April, 1976.

Table 9--Elements that can affect potential utilization of coals--content in 63 samples of coal from White Tail Butte area, in parts per million. (Reported on a whole-coal basis).

| Element | Range | Average | Average, Continental crust (Taylor, 1964) 1/ |
|---|---|---|---|
| As | <1 - 20 | 1.6 | 1.8 |
| Cd | L | L | .2 |
| Cu | 3.9 - 21.5 | 8.8 | 55 |
| F | <20 - 1.65 | 0.65 | 625 |
| Hg | <.02 - .23 | 0.10 | .08 |
| Li | L - 3.2 | <3.2 | 20 |
| Pb | L - 2.9 | <2.9 | 12.5 |
| Sb | 0.1 - 0.6 | 0.3 | .2 |
| Se | <.1 - 2.1 | 0.9 | .05 |
| Th | <3.0 - 17.8 | 4.4 | 9.6 |
| U | <0.2 - 8.3 | 0.9 | 2.7 |
| Zn | 2.3 - 13.4 | 8.4 | 70 |

1/ Taylor, S. R., 1964, Abundance of chemical elements in the continental crust: A new table: Geochim, et Cosmochim. A cta, v. 28, no. 8, p. 1273-1285.

and arsenic, are of interest because of the environmental problems that might occur if they are present in inordinate amounts; others such as thorium and uranium are of interest because they could be recovered from coal ash if they are present in sufficiently large quantities.

## OVERBURDEN - SOIL AND BEDROCK

### Description of Principal Soil Bodies

Soils of the White Tail Butte Study Area may be placed in two major categories based on their parent material and mode of development. These are: (1) residual soils, and (2) colluvial/alluvial soils. These two categories can be further subdivided on the basis of landform position. These include residual soils formed on: (1) ridges, (2) tabular divides, (3) footslopes, and (4) steeply sloping semi-badlands; and colluvial/alluvial soils developed: (1) on upland fans and footslopes, (2) in the bottom of intermittent drainages, and (3) on bottomland positions along natural drainages. Residual soils occupy about 90 percent of the study area; the colluvial/alluvial soils occur on about 10 percent of the area.

Residual soils on ridges and rolling uplands have stabilized with the climate, and erosion is not retarding soil development, except in localized tracts. Active erosion is common near bedrock outcrops on intermediate slopes and in tracts with adverse soil conditions. Soil deficiencies which may limit plant growth in these areas include salinity, sodicity, fine texture (clay-rich), and slow permeability.

These soils vary in depth from 7 inches to over 3 feet. Textures range from sandy loam to clay loam. In the moderately deep and deep soils, roots penetrate to about 3 feet. Plant-available moisture retained in these soils is approximately 2 inches per foot. Precipitation usually infiltrates the surface of these soils at a moderate rate and percolates downward at a moderate to slow rate until the soil mass holds it against gravitational pull or fine-textured bedrock is encountered.

These soils should provide an adequate supply of fair to good quality topsoiling material for revegetation with native range plants. However, stripping operations could be limited to some extent due to the variable soil depths and the local bedrock outcrops.

Point-Site soil profiles of shallow, moderately deep and deep residual soils occupying ridges and rolling uplands are described respectively in Tables 10, 11, and 12, Appendix D. The chemical properties of the upper 3 feet of these profiles should typify the soil mantle of most residual soils in this study area; below this depth, however, these properties may vary widely among the residual soils. Short- and mid-grass vegetation is dominant on these soils.

Residual soils on tabular divides are good sources of topsoiling material. They occur on about 10 percent of the study area. These moderately developed soils have a very permeable clay loam surface. Available moisture retained for plant use is about 2.2 inches per foot in these soils. The vegetation on these soils is composed primarily of mid- and short-grasses.

The Point-Site soil profile in Table 13, Appendix D, describes a residual soil occurring on a tabular divide in this study area.

On footslopes, residual soils have developed in weathered bedrock material under short- and mid-grass vegetation. Bedrock strata of the Fort Union Formation are the primary sources of parent materials for these soils; however, a few minor soils have formed in weathered bedrock derived from the Wasatch Formation.

Depth of these soils ranges from 7 inches to over 3.5 feet. The physical and chemical characteristics of these soils closely resemble those of the residual soils occupying ridges and tabular divides.

These soils should provide good quality planting media for the production of native range plants. However, uniform stripping of the soil material may be somewhat difficult due to the variability in soil depth.

Residual soils developing on steeply sloping semi-badlands are subject to very active erosional forces which remove the soil almost as rapidly as it is formed. The resulting soil profile is shallow, weakly developed, and closely resembles the underlying parent bedrock in its physical and chemical characteristics.

Sandstone, siltstone, shale, and baked rock outcrops are common in the semi-badlands terrain. The resultant soil material may be influenced by one or more of these members. Texture, salinity, sodicity, and color of these soils varies widely.

These soils represent a poor source of topsoiling material due to their shallowness and the extreme difficulty incurred in stripping the available material on steep slopes.

The Point-Site soil profile in Table 14, Appendix D, represents the more favorable conditions found on this land form.

The colluvial/alluvial soils occur on upland fans and footslopes, bottomland positions along natural drainages, and in the bottom of intermittent drainages. The parent materials of these soils were derived from eroded bedrock, residual soils in the uplands, and possibly alluvial terraces at higher elevations. The native vegetation occurring on these soils consists of mid- and short-grasses, scattered big sage, and several species of forbs.

Profile development ranges from slight in recently deposited sediments to moderate in soils on footslopes and upland terraces. Regardless of the stage of development, these soils are moderately permeable, calcareous in the subsoil layers, and retain about 2.2 inches of plant-available moisture per foot. The soil mantle, which extends to a depth of 5 feet or more, is non-saline and nonsodic. Textures range from sandy loam to clay loam.

The depth, permeability, moisture retention, and nonsaline-nonsodic nature of these soils will make them a valuable source of revegetative material for adapted plants, i.e., range, riparian, etc. Stripping operations should not be exceedingly difficult, except on local steep or complex slopes. Therefore, a relatively large supply of suitable soil material should be recoverable.

The Point-Site soil profiles in Tables 15, 16, and 17, Appendix D, typify the upper soil mantle of the colluvial/alluvial soils in this study area. However, below 3 feet in depth, soluble salt concentrations and physical properties may vary widely.

## Land Suitability Survey

A detailed land suitability survey of the White Tail Butte Study Area was made to evaluate and characterize the overburden (includes soil and bedrock) 1/ as a source of material for resurfacing and revegetating the area if it should be surface mined. This survey provides data on the quantity and quality of material for revegetation, ease of stripping and stockpiling the usable material, and other factors which affect the land's suitability as a source of material for revegetation. Basic data on the physical and chemical properties of the natural soil bodies and bedrock material under present conditions are also provided by the survey.

Land suitability specifications, shown on Table 18, were developed to establish classes for the specific use proposed, i.e., as a source of material for revegetation of surface-mined tracts. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes used in the Water and Power Resources Service land classification system.

Factors included in the specifications for quality consideration were: texture, salinity, sodicity, hydraulic conductivity, percent stones (>3 inches), erodibility, and available water holding capacity. Quantity considerations were based primarily on the depth of the material. Other factors influencing the ease with which suitable material could be selectively stripped and stockpiled were also considered. These included hard bedrock exposures (outcrops) and steep, rough, or complex slopes.

Class 1 lands provide the most desirable and plentiful source of soil material for revegetation. A large supply of highly suitable material, which is relatively easily stripped and stockpiled, should be available from this class of land. In addition to having an adequate amount of suitable material for reclaiming the immediate area, Class 1 land can probably provide borrow material for topdressing areas with insufficient suitable material. Class 2 lands have adequate resurfacing material, but it may be limited in quantity, less desirable in quality, or difficult to strip and stockpile. Class 3 lands are similar to those in Class 2, except the deficiencies are more pronounced or there is a combination of deficiencies. Land in this class is marginally suitable for revegetation, but under normal circumstances with good procedures for stripping and stockpiling, requirements for planting media can generally be met. Class 6 lands commonly lack adequate or suitable soil or bedrock material to meet the requirements for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from areas with adequate supplies or modify the material available for revegetation of the area.

Table 19 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

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1/ A glossary defining terms is included in Exhibit 4, Appendix D.

LAND SUITABILITY SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Overburden for Revegetation of Surface-Mined Areas
BLM/BR Cooperative Program EMRIA
Whitetail Butte Study Site

United States
Dept. of the Interior
Bureau of Reclamation
July 1976

| Overburden Characteristics | Symbols: Basic Subclass | Symbols: Information and Deficiencies | Class 1 | Class 2 | Class 3 |
|---|---|---|---|---|---|
| SOILS AND/OR BEDROCK | s | | | | |
| Textures | | | Fine sandy loams to clay loams | Sandy loam to silty clay loams | Loamy sand to clay |
| Coarse | | v | | Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly | Loamy sand in sufficient quantity to moderately reduce productivity, moisture retention, and may increase erosiveness moderately |
| Fine | | h | | Profile should have sufficient material for topdressing, clayey type materials that are slowly permeable should be placed below 6" in the reconstructed profile | Profile should have sufficient material for topdressing, placement of clay in reconstructed profile; permeable 10" plus; slowly permeable 30" plus |
| Depth | | d | > 36" of overburden that is suitable for plant media | >18" of overburden that is suitable for plant media | >10" of overburden that is suitable for plant media |
| Sodicity | | a | SAR not to exceed 9.0 in fine textured soils but may be 20.0 with loamy sand textures. Values can be slightly higher if compensated by adequate residual gypsum. | | |
| Salinity ($ECx10_3$) | | s | Less than 4 | Less than 8 but should have 10" of material of less than 4 for surface | Less than 12 but should have 10" of material of less than 4 for surface |
| Available Water Holding Capacity | | q | > 1.5"/foot of soil | >1.0"/foot of soil | > 0.75"/foot of soil |
| Hydraulic Conductivity | | p | Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion | Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate | Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion |
| Cobble and Stones (> 3") | | x | Less than 5% in soil mass | Less than 10% in soil mass | Less than 20% in soil mass |
| Weatherability 1/ | | | Will break down readily upon exposure to the weather | May require short period to break down upon exposure | May require extended period to break down |
| Erodibility | | | Susceptible to slight erosion | Susceptible to moderate erosion | Susceptible to severe erosion but can be controlled with proper management and placement |
| TOPOGRAPHY 2/ | t | | | | |
| Slope | | g | Permissible surface gradient 0 to 12 with smooth slopes | Permissible surface gradient 0 - 20% | Permissible surface gradient 0 - 35% |
| Indurated Sandstone Massive and lenticular | | r | None | 1 to 5% of area | 5 to 20% of area |
| Cover | | c | Not applicable | | |
| DRAINAGE | d | | Because of anticipated land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material, are not a factor in the classification. | | |
| Class 6 | | | Areas delineated in this class generally lack suitable material for stripping and stockpiling as surface material. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient surface soil and bedrock of suitable quality at or near the surface; (2) topography which prevents stripping including excessive slopes; (3) rocklands with large amounts of massive indurated surface sandstone; (4) toxic overburden (soil and bedrock), on or near the surface. Reclamation of lands will require material from outside the delineated area, from deep geologic strata or treatment of the available material. | | |

1/ Applicable only to bedrock material.
2/ Not applicable to bedrock material.

| Class Subclass | % of Area | Overburden Characteristics | Land Features | Manage Requirements |
|---|---|---|---|---|
| 1 | .32 | Land in this class has an average minimum depth of 36 inches of good and high quality overburden that is suitable for plant media. Usually this material is soil that has formed on deep alluvial, colluvial, and residual material. Medium texture is most common.<br><br>Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone.<br><br>Soil material in this class is nonsaline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous. | The surface relief comprises nearly level to gently sloping tabular divides, fans, foot slopes, and undulating uplands. This land is used for range. Topographic features will not hinder stripping and stock-piling. Selective stripping, where necessary, can be accomplished easily. Native mid and short grasses grow in association with scattered big and silver sage and some forbes. | These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-12 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum. |
| Less than 1 percent of Class 2t is included in this class. It is similar in all respects, except it has moderately steep slopes. | | | | |
| 2s | 20 | Land in this class has an average minimum depth of 18 inches of good quality overburden that is suitable for plant media. Usually this material is medium and moderately fine textured soil that has formed deep colluvial and alluvial deposits and moderately deep residual soils. Textures range from loam to clay loam. Good quality geologic material may be considered as a part of the 18-inch requirement. Below 18 inches the overburden is usually calcareous. Soil limitations other than depth include: clay rich layers, subsoil with high salinity, and layers that are saline and sodic.<br><br>Soil aggregates of these soils have fair to good stability and water enters the material at a moderate rate, but the internal water movement is adequate to provide aeration of the primary plant root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity. Saline and/or sodic material for use as sub-surface material will equilibrate at a low salinity/sodic level from the downward movement of the rainfall. | The surface relief comprises nearly level to rolling foot slopes, side slopes, swales, and undulating uplands. Topographic features will not hinder stripping and stock-piling desirable material; also, selective stripping can be accomplished easily. Native mid and short grasses grow in association with scattered big sage, silver sage, and some forbes. This land is used for range. | Selection of the maximum depth of suitable material for use at or near the surface will require a review of the field data. Selective stripping and stock-piling to isolate surface and subsurface material followed by selective placement is necessary for the best use of available material in this land class.<br><br>With proper selection and placement, reclamation should not be difficult and average management should assure successful permanent revegetation. |
| 2st | 4 | The general description of overburden characteristics of Class 2s applies to this class. The most common soil limitations are depth of soil mantle and permeable material that is highly saline. | The surface relief comprises gently to steeply sloping land areas between the ridge crests and natural drainageways. Complex slope pattern is common in this class and this makes selective stripping more difficult. There will be some mix of surface and subsurface material. There are, however, some single plane and undulating simple slope patterns but they are not common. Native vegetation is similar to Class 2s. This land is used for grazing. | A review of the field data to determine the effect of unavoidable mixing of surface and subsurface material should be a part of the mining plan. This would determine best stripping depths. These data will also be a guide for placement of this material in a reconstructed profile. The last paragraph describing management of Class 2s applies to this class also. |

| Class Subclass | % of Area | Overburden Characteristics | Land Features | Management Requirements |
|---|---|---|---|---|
| 3s | 6 | Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material is medium to moderately fine textured soil that has formed on alluvial and colluvial deposits and residual material. The principal limiting soil factor is the limited quantity of nonsaline material for use at or near the surface. The subsoil and substratum are often highly saline. The infiltration rate is moderately slow but internal water movement is only moderately restricted and the soluble salts can be leached. Laboratory tests also indicate fair to good permeability. Land in this class retains a large quantity of water for plant use.<br><br>Locally clay rich soils and sodic soils occur and will be included in the stockpiled material for plant media, but they occur only as minor inclusions. Their impact on the stockpiled material will be minimal. | The surface relief comprises nearly level uplands, gently sloping foot slopes, and fans. Topographic features will not hinder stripping and stockpiling desirable material and selective stripping, if required, can be accomplished easily. Native mid and short grasses grow in association with scattered big sage and forbes. This land is used for grazing | These soils will be slightly susceptible to water erosion. This hazard can be minimized by roughing the surface of the reconstructed profile. Pitting or gouging basins and mulching will retard erosion. Mulches can also be used to reduce erosion. These measures can increase the effective leaching of soluble salts below the primary root zone and increase production. Successful permanent revegetation can be accomplished, but above average planning and management will be required. For best use of the soil in this class, the surface material must be stripped and stockpiled separately from the subsoil and substratum. |
| 3st | 21 | Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material consists of medium and moderately fine texture residual soil and/or weathered shaley parent material. The major soil limitation is quantity of nonsaline material. Shale exposures are common along ridge crests and near sandstone outcrops. Immediately below the shallow soil mantle the shaley parent material is often highly saline.<br><br>Locally the bedrock material near the land surface is permeable and the soluble salts can be leached. Small tracts with clay rich and sodium affected layers that will most likely be included in the stockpiled material occur as inclusions. | The surface relief of land in this class is characterized by complex gentle to steep slopes below ridge crests. Erosion is active on the steeper slopes and many small areas of shale and sandstone outcrops are visible. Steep slopes, sandstone and shale outcrops, and dendritic drainage patterns will make uniform stripping impossible. Native mid and short grasses grow in association with scattered big and silver sage and some forbes. This land is used for range. | Selective stripping with emphasis on stripping small tracts of deep soil separately should be considered. Prior to a review of the data, a field check to locate these tracts of deep suitable material is advisable. This action should be a part of developing the mining plan and for mining operations. Similar surface treatment of reconstructed profiles as described in 3s should be followed. |
| 6st | 17 1/ | Land in this class has less than 10 inches average depth of fair and good quality overburden that is suitable for plant media. These shallow residual soils have formed on weathered shaley material. Sandstone and shale outcrops are common. The underlying residual formation is quite variable in physical and chemical properties. High salinity, slow permeability, and clay rich layers are the most common soil limitations. These limitations occur singly or in combination in most delineated areas in this class. However, small inclusions of deeper surface soils and of permeable nonsaline, nonsodic geologic material are also present in most delineated areas. | The surface relief in this class comprises steep slopes below ridge crests. Active erosion locally may expose sandstone or shale in up to 25 percent of any tract. The dendritic drainage pattern creates complex slopes that preclude uniform selective stripping of most tracts. Locally the topography is favorable for selective stripping some of the deeper soils. Native med and short grasses grow in association with forbes and sedges. This land is used for range. | Tracts with deeper soils and good quality geologic strata, though small, should be selectively stripped. Modification by leaching should be considered if water is available. Roughing the surface, pitting, and gouging basins can also increase infiltration and leaching. Borrow material will be required for successful permanent revegetation. The postmining soil profile and vegetative cover will be an improvement over present conditions. |

1/ Includes a small acreage of Class 6s.

The land suitability survey was accomplished using Water and Power Resources Service methods and procedures. Field mapping was done on aerial photographs with a scale of 1:4,800. Topographic drawings at a scale of 1:24,000 with 20-foot contour intervals were used for reference. An Abney hand level was used to supplement the slope data on topographic drawings.

Representative (Point-Site) soil profiles typical of extensive areas of Class 1, 2, 3, and 6 lands were described, sampled, and analyzed in detail. Additional profiles were recorded in the heterogeneous soil areas to show variations within the delineated areas. This information was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are often located in transitional tracts between soil types to more accurately locate boundaries.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger or hydraulic coring machine was then used to penetrate the overburden to a depth of 10 feet unless hard bedrock was encountered. Soil structure, texture, consistence, color, and other observable features of the exposed profile such as salinity, sodicity, and root distributions were recorded. Lime content was checked with dilute hydrochloric acid. Samples were collected from many of the exposed profiles. Evaluation of the soil material for hydraulic conductivity and available water holding capacity in relation to the reclaimed profile was a major consideration in the field evaluation. Using these basic soil evaluations along with observations of other land features such as surface stones, exposed hard bedrock, and slope, a land suitability class was tentatively assigned each delineated area while in the field. The suitability classes, when finalized, were recorded on land classification maps, Plates 26 through 30.

A soil laboratory was used in connection with the land suitability survey and screenable tests were performed on all soil samples. These tests included disturbed hydraulic conductivity, salinity, pH, and moisture retention (at 15 bars). More detailed soil analyses were then made as required. Exhibit 1, Appendix D, describes the screenable testing procedures used in the laboratory.

Complete soil analyses were performed on all samples from Point Site profiles representative of the major soil categories for the land suitability survey and the soil inventory. The analyses listed in Exhibit 3, Appendix D, were performed as needed for proper overburden evaluation.

In addition to the foregoing testing program, greenhouse studies were conducted on soil and bedrock samples from this study area to indicate possible toxic or other unfavorable conditions for plant growth (see GREENHOUSE section).

## Results of Land Suitability Survey

The results of the land suitability survey are recorded graphically on detailed drawings, Plates 26 through 30, which show the areal distribution of the various land classes, soil deficiencies, topographic deficiencies, profile notes of soil borings, and the results of laboratory analyses. This information is also summarized on Plates 31 and 32. Plate 31 describes the location

and depth of overburden that is suitable for use at or near the surface in postmining reconstructed profiles. Plate 32 shows the location and quantity of subhorizon material that can be used below the primary plant root zone in reconstructed profiles. Soil deficiencies are also shown. The following tabulation lists the acres of land in each section by classes and subclasses.

White Tail Butte Study Area

| Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T.56N.,R.72W. | 1 | 2t | 2s | 2st | 3s | 3st | 6st | Total |
| Sec. 30 | 138.5 | | 139.4 | | 102.4 | | 119.7 | 500 |
| Sec. 31 | 156.2 | | 36.3 | | | 174.9 | 122.6 | 490 |
| Sec. 32 | 180.1 | | 113.8 | | 14.7 | 223.0 | 138.4 | 670 |
| T.56N.,R.73W. | | | | | | | | |
| Sec. 24 | 65.0 | | 36.0 | | | 59.0 | | 160 |
| Sec. 25 | 243.2 | 14.4 | 157.5 | 101.0 | 41.4 | 53.4 | 25.1 | 636 |
| TOTAL | 783.0 | 14.4 | 483.0 | 101.0 | 158.5 | 510.3 | 405.8 | 2456 |
| Percent of Area | 32 | < 1 | 20 | 4 | 6 | 21 | 17 | |

The results in the table above indicate that 83 percent of the land in the White Tail Butte Study Area contains an adequate supply of suitable material to meet the requirements for revegetation. Suitable plant material will usually exceed the revegetation requirements in Classes 1 and 2, will be adequate in Class 3, and will be deficient in Class 6. About 25 percent of the land will require additional material for planting media. Seventeen percent of the land is in Class 6; the remaining 8 percent occurs as small, interspersed inclusions in Classes 1, 2, and 3.

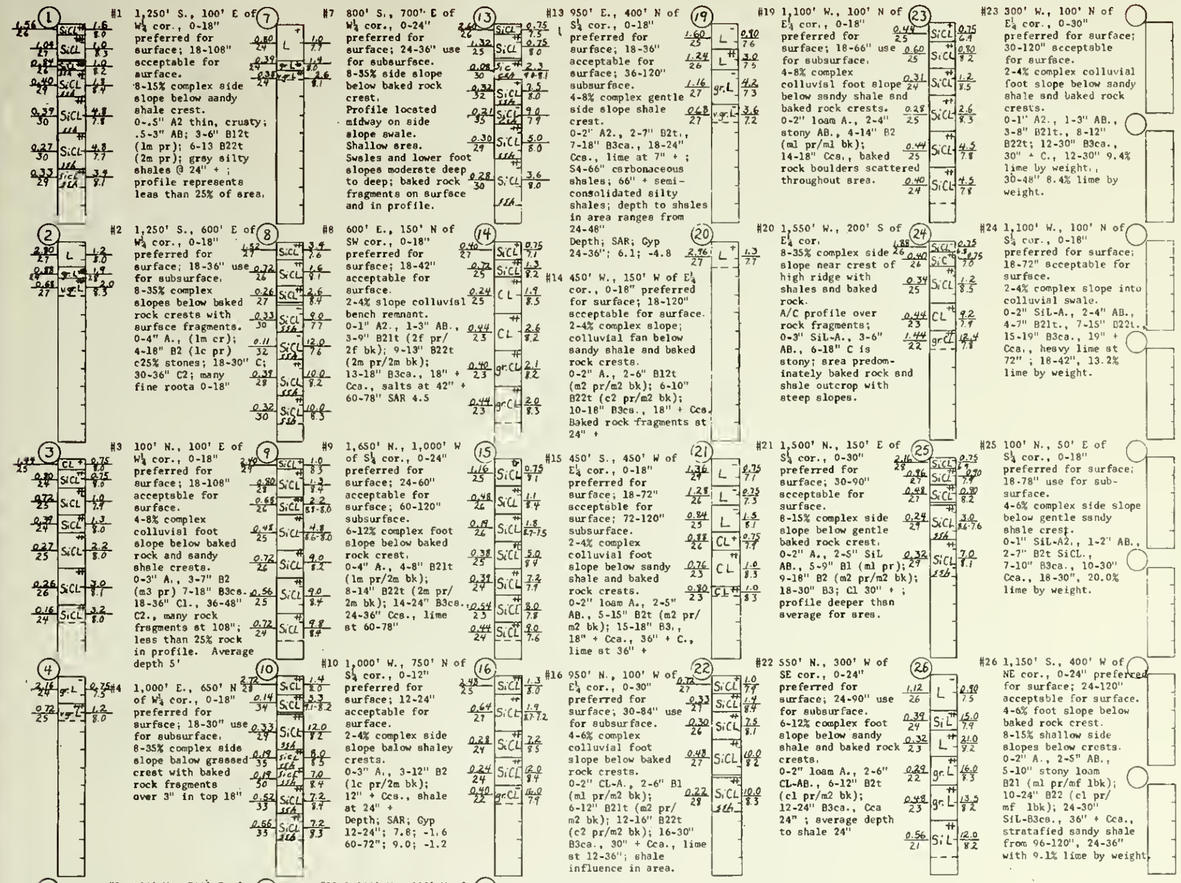
This land suitability survey provides adequate data for developing the reclamation portion of the mining plan; however, it does not provide adequate detail for stripping and stockpiling procedures during the surface mining operation. Additional field borings and observations supported by laboratory data may be required to more accurately determine the quantity, quality, and location of available material to be stripped and stockpiled for use as revegetative media.

## Overburden Suitability

### Soil Mantle Suitability

In general, the natural mix of deep residual and colluvial/alluvial soils in this study area should provide an adequate supply of suitable topsoiling material for revegetation if surface mining occurs.

The A and B horizons of most soils in this study area are nonsaline, nonsodic, permeable, and well suited for topdressing contoured mine spoils. Most of



#1 1,250' S., 100' E of W¼ cor., 0-18" preferred for surface; 18-108" acceptable for surface. 8-15% complex side slope below sandy shale crest. 0-.5" A2 thin, crusty; .5-3" AB; 3-6" B12t (1m pr); 6-13 B22t (2m pr); gray silty shales @ 24" + ; profile represents less than 25% of area.

#2 1,250' S., 600' E of W¼ cor., 0-18" preferred for surface; 18-36" use for subsurface. 8-35% complex slopes below baked rock crests with surface fragments. 0-4" A., (1m cr); 4-18" B2 (1c pr) c25% stones; 18-30" C; 30-36" C2; many fine roots 0-18"

#3 100' N., 100' E of W¼ cor., 0-18" preferred for surface; 18-108" acceptable for surface. 4-8% complex colluvial foot slope below baked rock and sandy shale crests. 0-3" A., 3-7" B2 (m3 pr) 7-18" B3ca. 18-36" C1., 36-48" C2., many rock fragments at 108"; less than 25% rock in profile. Average depth 5'

#4 1,000' E., 650' N of W¼ cor., 0-18" preferred for surface; 18-30" use for subsurface. 8-35% complex side slope below grassed crest with baked rock fragments over 3" in top 18"

#5 900' N., 700' E of W¼ cor., 0-12" preferred for surface; 12-84" use for subsurface. 2-4% colluvial foot slope below baked rock crest. 0-2" A., 2-5" AB., 5-13" B21t (2m pr/ 3m bk); 13-18" B22t (c2 pr/m2 bk); 18-36' B3ca (cl pr/ m2 bk); with lime; 36-54" Cca., 54-72" C2.

#6 1,450' E., 150' S of W¼ cor., 0-12" preferred surface material; 12-36" acceptable for surface; 36-96" use for subsurface. 6-8% complex colluvial foot slope below sandy shale and baked rock crests. 0-3" A., 3-12" B2 (ml pr/m2 bk); 12-24" B3ca., 24" Cca., surface 48" from baked rock; 54" + from shale; salts at 66" + ; lime at 12"

#7 800' S., 700' E of W¼ cor., 0-24" preferred for surface; 24-36" use for subsurface. 8-35% side slope below baked rock crest. Profile located midway on side slope swale. Shallow area. Swales and lower foot slopes moderate deep to deep; baked rock fragments on surface and in profile.

#8 600' E., 150' N of SW cor., 0-18" preferred for surface; 18-42" acceptable for surface. 2-4% slope colluvial bench remnant. 0-1" A2., 1-3" AB., 3-9" B21t (2f pr/ 2f bk); 9-13" B22t (2m pr/2m bk); 13-18" B3ca., 18" + Cca., salts at 42" + 60-78" SAR 4.5

#9 1,650' N., 1,000' W of S¼ cor., 0-24" preferred for surface; 24-60" acceptable for surface; 60-120" subsurface. 6-12% complex foot slope below baked rock crest. 0-4" A., 4-8" B21t (1m pr/2m bk); 8-14" B22t (2m pr/ 2m bk); 14-24" B3ca., 24-36" Cca., lime at 60-78"

#10 1,000' W., 750' N of S¼ cor., 0-12" preferred for surface; 12-24" acceptable for surface. 2-4% complex side slope below shaley crests. 0-3" A., 3-12" B2 (1c pr/2m bk); 12" + Cca., shale at 24" + Depth; SAR; Gyp 12-24"; 7.8; -1.6 60-72"; 9.0; -1.2

#11 1,100' W., 300' N of S¼ cor., 0-18" preferred for surface; 18-120" acceptable for surface. 4-6% complex foot slope below sandy shale crest. 0-1" A2., 1-4" BA., 4-10" B2t (2m pr/ 2m bk); 10-18" B3ca., 18-42" Cca., baked rock fragments at 60" and increase to 84" + ; lime 10" +

#12 400'N., 50' W of S¼ cor., 0-12" preferred for surface; 12-120" acceptable for surface. 4-8% complex foot slope below sandy shale crest. 0-.5" A2., .5-3" AB., 3-7" B2t., 7-11" B3ca., 11-24" Cca., mottled grayish shales; lime at 7" +

#13 950' E., 400' N of S¼ cor., 0-18" preferred for surface; 18-36" acceptable for surface; 36-120" subsurface. 4-8% complex gentle side slope shale crest. 0-2" A2., 2-7" B2t., 7-18" B3ca., 18-24" Cca., lime at 7" + ; 54-66" carbonaceous shales; 66" + semi-consolidated silty shales; depth to shales in area ranges from 24-48" Depth; SAR; Gyp 24-36"; 6.1; -4.8

#14 450' W., 150' W of E¼ cor., 0-18" preferred for surface; 18-120" acceptable for surface. 2-4% complex slope; colluvial fan below sandy shale and baked rock crests. 0-2" A., 2-6" B12t (m2 pr/m2 bk); 6-10" B22t (c2 pr/m2 bk); 10-18" B3ca., 18" + Cca. Baked rock fragments at 24" +

#15 450' S., 450' W of E¼ cor., 0-18" preferred for surface; 18-72" acceptable for surface; 72-120" subsurface. 2-4% complex colluvial foot slope below sandy shale and baked rock crests. 0-2" loam A., 2-5" AB., 5-15" B2t (m2 pr/ m2 bk); 15-18" B3., 18" + Cca., 36" + C., lime at 36" +

#16 950' N., 100' W of E¼ cor., 0-30" preferred for surface; 30-84" use for subsurface. 4-6% complex colluvial foot slope below baked rock crests. 0-2" CL-A., 2-6" B1 (ml pr/m2 bk); 6-12" B21t (m2 pr/ m2 bk); 12-16" B22t (c2 pr/m2 bk); 16-30" B3ca., 30" + Cca., lime at 12-36"; shale influence in area.

#17 1,050' S., 700' W of NE cor., 0-30" preferred for surface; 30-120" use for subsurface. 8-35% complex foot slope below baked rock crests. 0-2" loam A., 2-8" stony loam B1 (ml pr/ml bk); 8-30" stony B2; 30" + Cca., shale at 108" + ; stony reddish-brown loam soil; upper slopes have less than 10" of coarse very stony loam.

#18 1,500' W., 850' N of E¼ cor., 0-18" preferred for surface; 18-120" acceptable for surface. 2-4% complex colluvial foot slope below sandy shale and baked rock crests. 0-2" loam A., 2-5" B12t (ml pr/f2 bk); 5-11" SiC., B22t (m2 pr/m2 bk); 11-18" B3ca., 18" + Cca.

#19 1,100' W., 100' N of E¼ cor., 0-18" preferred for surface; 18-66" use for subsurface. 4-8% complex colluvial foot slope below sandy shale and baked rock crests. 0-2" loam A., 2-4" stony AB., 4-14" B2 (ml pr/ml bk); 14-18" Cca., baked rock boulders scattered throughout area.

#20 1,550' W., 200' S of E¼ cor. 8-35% complex side slope near crest of high ridge with shales and baked rock. A/C profile over rock fragments; 0-3" SiL-A., 3-6" AB., 6-18" C is stony; area predominately baked rock and shale outcrop with steep slopes.

#21 1,500' N., 150' E of S¼ cor., 0-30" preferred for surface; 30-90" acceptable for surface. 8-15% complex side slope below gentle baked rock crest. 0-2" A., 2-5" SiL AB., 5-9" B1 (ml pr); 9-18" B2 (m2 pr/m2 bk); 18-30" B3; C1 30" + ; profile deeper than average for area.

#22 550' N., 300' W of SE cor., 0-24" preferred for surface; 24-90" use for subsurface. 6-12% complex foot slope below sandy shale and baked rock crests. 0-2" loam A., 2-6" CL-AB., 6-12" B2t (c1 pr/m2 bk); 12-24" B3ca., Cca 24" ; average depth to shale 24"

#23 300' W., 100' N of E¼ cor., 0-30" preferred for surface; 30-120" acceptable for surface. 2-4% complex colluvial foot slope below sandy shale and baked rock crests. 0-1" A2., 1-3" AB., 3-8" B21t., 8-12" B22t; 12-30" B3ca., 30" + C., 12-30" 9.4% lime by weight., 30-48" 8.4% lime by weight.

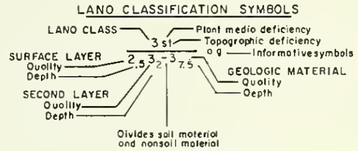
#24 1,100' W., 100' N of S¼ cor., 0-18" preferred for surface; 18-72" acceptable for surface. 2-4% complex slope into colluvial swale. 0-2" SiL-A., 2-4" AB., 4-7" B21t., 7-15" D22t., 15-19" B3ca., 19" + Cca., heavy lime at 72" ; 18-42", 13.2% lime by weight.

#25 100' N., 50' E of S¼ cor., 0-18" preferred for surface; 18-78" use for subsurface. 4-6% complex side slope below gentle sandy shale crest. 0-1" SiL-A2., 1-2" AB., 2-7" B2t SiCL., 7-10" B3ca., 10-30" Cca., 18-30", 20.0% lime by weight.

#26 1,150' S., 400' W of NE cor., 0-24" preferred for surface; 24-120" acceptable for surface. 4-6% foot slope below baked rock crest. 8-15% shallow side slopes below crests. 0-2" A., 2-5" AB., 5-10" stony loam B21 (ml pr/mf lbk); 10-24" B22 (c1 pr/ mf lbk); 24-30" SiL-B3ca., 36" + Cca., stratafied sandy shale from 96-120", 24-36" with 9.1% lime by weight.

## EXPLANATION

### LAND CLASSIFICATION SYMBOLS




### INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant medio)

- o Sodicity
- s Salinity
- h Clay(very fine texture)
- v Coarse(very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- i Massive lenticular sandstone and/or Glacial erratics
- e Erosion

### SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

(3) SOIL PROFILE NUMBER

C.L. — 2.8---2.8 EC.mmhos/cm. Bat. Est.
8.4-8.0 8.4 pH; 5 Salt-Water Suspension
8.0 pH Salt-Ca Cl2 Suspension
.65 Hydraulic Conductivity in/hr (Disturbed Samples)
Lr.C — .65 / 24 — 24 Settling Volume
Gr.

### SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gr | Gravel |
| S | Sand |
| L S | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SiL | Silt Loam |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SiCL | Silt Clay Loam |
| SC | Sandy Clay |
| C | Clay |
| SiC | Silty Clay |
| Sh | Shale |
| Ss | Sandstone |
| F | Fine |
| Lt | Light |
| M | Medium |
| H | Heavy |

### STRUCTURE ABREVIATIONS

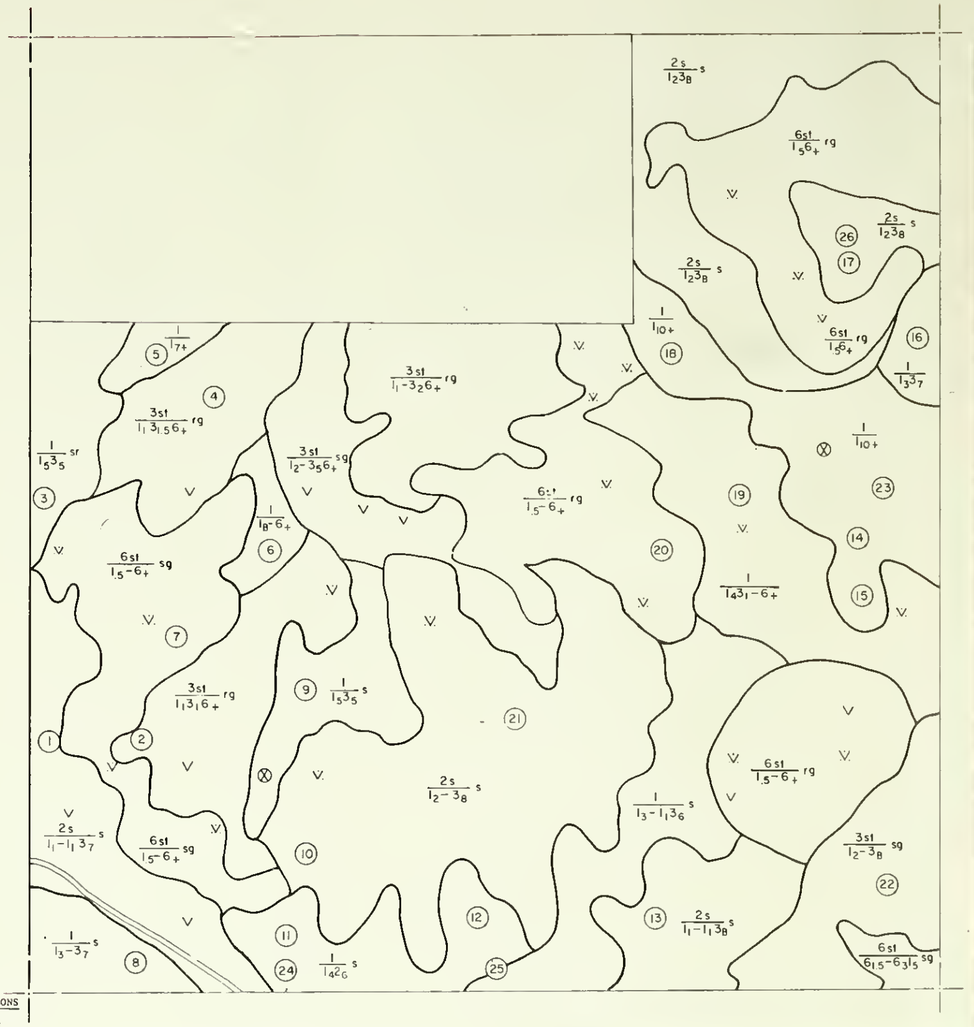
Size
- very fine .....vf
- fine .....f
- medium .....m
- coarse .....c
- very coarse ....vc

Grade
- structureless ..0
- weak .....1
- moderate .....2
- strong .....3

Type
- platy .....pl
- prismatic .....pr
- columnar .....cpr
- blocky .....bk
- angular blocky .abk
- subangular blocky .sbk
- granular .....gr
- crumb .....cr
- single grain ...sg
- massive .....m

### MISCELLANEOUS ABREVIATIONS

- calcic horizon .....Ca
- sodium adsorption-ratio ...SAR
- settling volume .....SV
- creviced rock ....CR



### CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock-clinker (local name scoria)
- Slide or slipfaps point upslope
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Well spot

PITS
- Gravel
- Mine

DAMS
- Medium or small

1:4800
SECTION 30, T.56 N.-R.72 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

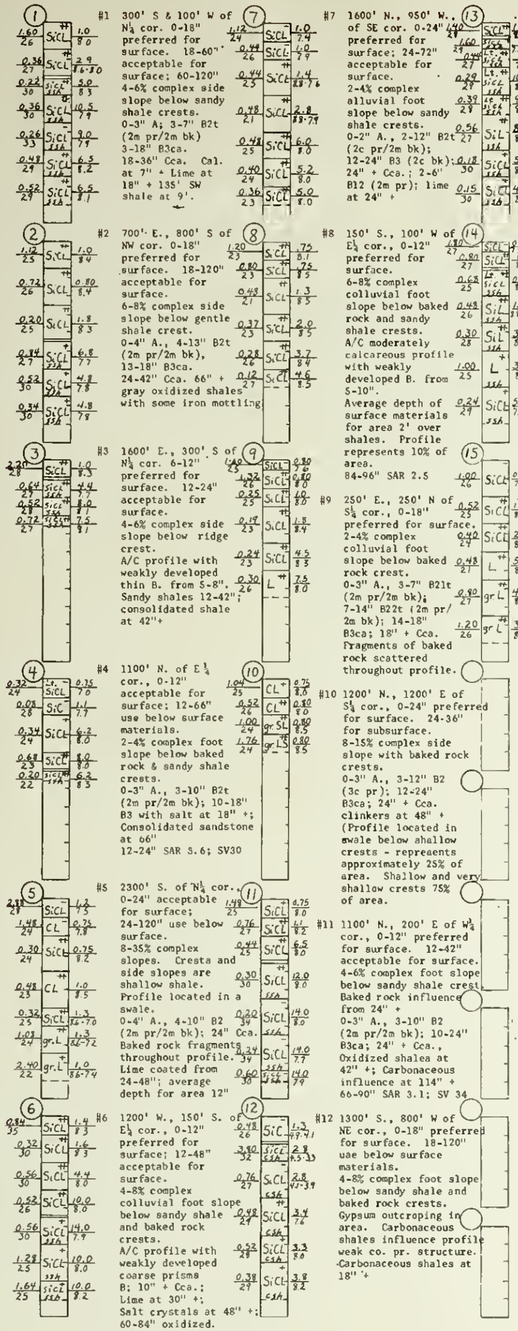
RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD - WYOMING

# DETAIL LAND CLASSIFICATION

SOILS - T. FIECHTL — SUBMITTED
DRAWN - L. E. ALLSUP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — JUNE 1977 — 1305-600-140



#1 300' S & 100' W of N¼ cor. 0-18" preferred for surface. 18-60" acceptable for surface; 60-120" 4-6% complex side slope below sandy shale crests. 0-3" A; 3-7" B2t (2m pr/2m bk) 3-18" B3ca. 18-36" Cca. Cal. at 7" + Lime at 18" + 135' SW shale at 9'.

#2 700' E., 800' S of NW cor. 0-18" preferred for surface. 18-120" acceptable for surface. 6-8% complex side slope below gentle shale crest. 0-4" A., 4-13" B2t (2m pr/2m bk), 13-18" B3ca. 24-42" Cca. 66" + gray oxidized shales with some iron mottling

#3 1600' E., 300' S of N¼ cor. 6-12" preferred for surface. 12-24" acceptable for surface. 4-6% complex side slope below ridge crest. A/C profile with weakly developed thin B. from 5-8". Sandy shales 12-42"; consolidated shale at 42"+

#4 1100' N. of E¼ cor., 0-12" acceptable for surface; 12-66" use below surface materials. 2-4% complex foot slope below baked rock & sandy shale crests. 0-3" A., 3-10" B2t (2m pr/2m bk); 10-18" B3 with salt at 18" +; Consolidated sandstone at 66" 12-24" SAR 3.6; SV30

#5 2300' S. of N¼ cor., 0-24" acceptable for surface; 24-120" use below surface. 8-35% complex slopes. Cresta and side slopes are shallow shale. Profile located in a swale. 0-4" A., 4-10" B2 (2m pr/2m bk); 24" Cca. Baked rock fragments throughout profile. Lime coated from 24-48"; average depth for area 12"

#6 1200' W., 150' S. of E¼ cor., 0-12" preferred for surface; 12-48" acceptable for surface. 4-8% complex colluvial foot slope below sandy shale and baked rock crests. A/C profile with weakly developed coarse prisms B; 10" + Cca.; Lime at 30" +; Salt crystals at 48" +; 60-84" oxidized. Twenty-five percent of area has 2' of surface matcrial

#7 1600' N., 950' W., of SE cor. 0-24" preferred for surface; 24-72" acceptable for surface. 2-4% complex alluvial foot slope below sandy shale crests. 0-2" A., 2-12" B2t (2c pr/2m bk); 12-24" B3 (2c bk); 24" + Cca.; 2-6" B12 (2m pr); lime at 24" +

#8 150' S., 100' W of E¼ cor., 0-12" preferred for surface. 6-8% complex colluvial foot slope below baked rock and sandy shale crests. A/C moderately calcareous profile with weakly developed B. from 5-10". Average depth of surface materials for area 2' over shales. Profile represents 10% of area. 84-96" SAR 2.5

#9 250' E., 250' N of S¼ cor., 0-18" preferred for surface. 2-4% complex colluvial foot slope below baked rock crest. 0-3" A., 3-7" B21t (2m pr/2m bk); 7-14" B22t (2m pr/2m bk); 14-18" B3ca; 18" + Cca. Fragments of baked rock scattered throughout profile.

#10 1200' N., 1200' E of S¼ cor., 0-24" preferred for surface. 24-36" for subsurface. 8-15% complex side slope with baked rock crests. 0-3" A., 3-12" B2 (3c pr); 12-24" B3ca; 24" + Cca. clinkers at 48" + (Profile located in swale below shallow crests - repreaents approximately 25% of area. Shallow and very shallow crests 75% of area.

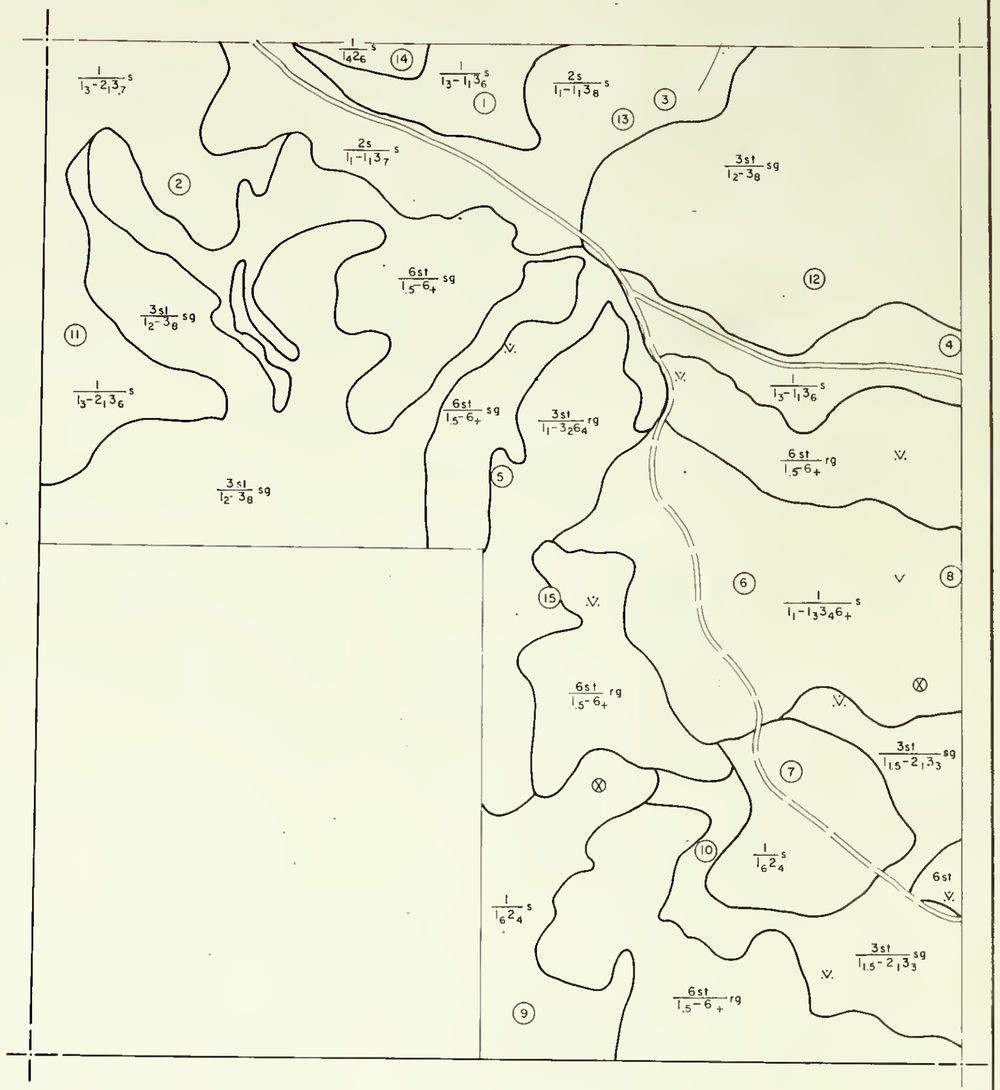
#11 1100' N., 200' E of W¼ cor., 0-12" preferred for surface. 12-42" acceptable for surface. 4-6% complex foot slope below sandy shale crest. Baked rock influence from 24" + 0-3" A., 3-10" B2 (2m pr/2m bk); 10-24" B3ca; 24" + Cca., Oxidized shales at 42" +; Carbonaceous influence at 114" + 66-90" SAR 3.1; SV 34

#12 1300' S., 800' W of NE cor., 0-18" preferred for surface. 18-120" use below surface materials. 4-8% complex foot slope below sandy shale and baked rock crests. Gypsum outcroping in area. Carbonaceous shales influence profile weak co. pr. structure. Carbonaceous shales at 18" +

#13 700' E., 400' S of N¼ cor., 0-12" preferred for surface. 12-120" use below surface. 4-6% complex side slope below gentle shallow sandy shale crest. See Master Site No. for profile description

#14 400' E., 100' S of E¼ cor., 0-18" preferred for surface. 18-120" use below surface. 2-4% complex side slope below sandy shale crest 0-1" Sil-A., 1-3" AB., 3-6" B2t., 6-15" B3ca., 15-18" Cca., 18" + CR lime accumulations 15" +., 18-36", 16.8% lime by weight. Semi consolidated sandy shales 36" +

#15 2000'E., 300'S of E ½ Cor., 0-24" preferred for surface; 4-6% swale at base of rocky baked rock crest. 0-3" Sil-A., 3-7" C1-AB., 7-12"-B21t, 12-24: B22t-24-42", B3ca-42" + Cca - lime accumulations at 42-60". 24-42" with 4.6% lime by weight.



## EXPLANATION

### LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant medio deficiency; Topographic deficiency; o g — Informative symbols

SURFACE LAYER — Quality, Depth — 2,5 3 2-3 7,5

SECOND LAYER — Quality, Depth

GEOLOGIC MATERIAL — Quality, Depth

Divides soil material and nonsoil material

### INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant medio)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics
- c Cover

### SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

3 SOIL PROFILE NUMBER

C.L. — 2.8 - - - 2.8 EC. mmhos/cm. Bot. Est; 8.4-8.0 8.4 pH: B Soil—Water Suspension; 8.0 pH Soil—CaCl2 Suspension

Lt. C — .65 Hydraulic Conductivity in/hr. (Disturbed Sample); 24 Settling Volume

Gr.

.65/24

SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gr | Gravel |
| S | Sand |
| LS | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SIL | Silt Loam |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SICL | Silt Clay Loam |
| SC | Sandy Clay |
| C | Clay |
| SIC | Silty Clay |
| Sh | Shale |
| Ss | Sandstone |
| F | Fine |
| Lt | Light |
| M | Medium |
| H | Heavy |

STRUCTURE ABREVIATIONS

Size: very fine .....vf; fine .....f; medium .....m; coarse .....c; very coarse ....vc

Grade: structureless ..0; weak .....1; moderate .....2; strong .....3

Type: platy .....pl; prismatic .....pr; columnar .....cpr; blocky .....bk; angular blocky .abk; subangular blocky .sbk; granular .....gr; crumb .....cr; single grain ...sg; massive .....m

MISCELLANEOUS ABREVIATIONS

calcic horizon .....Ca; sodium adsorption-ratio ...SAR; settling volume .....SV; creviced rock.... CR

### CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES: Blowout; Clay spot; Gravelly spot; Gumbo, slick or scaby spot (sodic); Dumps and similar nonsoil areas; Rock outcrop (includes shale and sandstone); Baked rock - clinker (local name scoria); Slide or slip (tips point upslope); Stony spot, very stony spot; Greasewood

WATER FEATURES: Marsh or swamp; Spring; Well, artesian; Well, irrigation; Wet spot

PITS: Gravel; Mine

DAMS: Medium or small

1:4800

SECTION 31, T. 56 N.-R. 72 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING

# DETAIL LAND CLASSIFICATION

SOILS: T. FIECHTL — SUBMITTED
DRAWN: S. E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — JUNE 1977 — 1305-600-141

#1 1,000' S., 300' E of W¼ cor., 0-12" preferred for surface; 12-24" acceptable for surface. 2-4% complex colluvial foot slope below sandy shale and baked rock crests. 0-3" A., 3-11" B2t (2m pr/2m bk); 11-24" B3ca., 24" + Cca., baked rock fragments throughout profile.

#2 550' N., 300' E of W¼ cor., 0-24" preferred for surface; 24-42" use below surface materials. 4-6% complex foot slope below baked rock crest. 0-2" A., 2-10" B21t (2m pr/2m bk); 11-24" B22t (2c pr/2m bk); 24" + Cca., oxidized from 42-54" and 108-120" ; shales mostly gray and sandy.

#3 1,600' N., 650' W of S¼ cor., 0-12" acceptable for surface; 12-120" use below surface materials. 6-8% complex alluvial side slope below sandy shale crest. 0-3" A., 3-7" B2t (3m pr/2m bk); 7-12" B3ca., 12" + Cca., lime accumulations 90-102", buried profile at 112" +

#4 1,000' N., 650' W of S¼ cor., 0-12" preferred for surface; 12-120" use below surface materials. 2-4% complex side slope below shale crest. 0-5" AB., 5-10" B2t (2m pr/2m bk); 10-18" B3ca., 18" + Cca., salt crystals 30" +, shallow profiles on upper levels and crest.

#5 1,050' N., 150' W of S¼ cor., 0-24" preferred for surface; 24-120" use below surface materials. 4-8% complex alluvial soil below sandy shale crest; swale profile. 0-4" AB., 4-12" B2t (2m pr/2m bk); 12-24" B3ca., 24" + Cca., lime 12" +

#6 1,000' E., 450'N of S¼ cor., 0-12" preferred for surface; 12-120" use below surface materials. 4-6% complex side slope below sandstone crest. 0-1" A2., 1-4" AB., 4-9" B2 (ml pr/2m bk); 9-12" B3ca (cl pr/ml pr); 12-24" CR., shales with weak development., 24' + consolidated soft sandstone; profile 90' W., 6' to shales; salt crystals at 60" +

#7 800' N., 900' W of SE cor., 0-12" preferred for surface; 12-120" use below surface materials. 6-12% complex alluvial foot slope below sandy shale and sandstone crests. 0-1" A2., 1-3" AB., 3-7" B2 (m2 pr/m2 bk); 7-24 B3ca., 24" + Cca., crusty at 24" + ; fragmented soft sandstone at 84-96"

#8 850' N., 350' E of S¼ cor., 0-24" preferred for surface; 24-78" acceptable for surface. 2-4% small alluvial terrace with side slopes up to 35%. 0-1" A2., 1-5" AB., 5-11" B21t (m2 pr/m2 bk); 11-15" B22t (m2 pr/m2 bk); 15-24" B3., 24" + Cca., 78" +, stratified with oxidation influence.

#9 200' W., of S¼ cor., 0-18" acceptable for surface; 18-120" use below surface materials. 2-4% complex alluvial bench. 0-½" A2., ½-3" AB., 2-7" B2t (m2 cpr/2f bk); 7-12" B3ca., 12" + Cca., slick spots in area.

#10 950' N., 950' E of SW cor., 0-12" preferred for surface; 12-42" acceptable for surface; 42-120" subsurface material. 4-8% complex colluvial fan below sandy shale and sandstone crests. 0-3" A., 3-9" B (cl pr/2m bk); 9-18" B3ca., 18" + Cca., some shale influence in area at 20"

#11 1,400' E., 300' N of W¼ cor., 0-12" preferred for surface; 12-54" acceptable for surface; 54-120" subsurface material. 8-12% complex colluvial side slope below sandy shale and sandstone crests. Gullies with 35-75% slope in area. 0-4" A horizon with crusty surface A2., 4-7" AB., 7-30" B3ca., 30" + Cca., carbonaceous shales at 96" + ; site a dump alluvial fill with surrounding area being less than 2' to shale.

#12 1,900' S., 150' E of N¼ cor., 0-18" preferred for surface; 18-102" acceptable for surface; 102-120" subsurface material. 2-4% slope complex residual terrace remnant. 0-2" A2 crusty., 2-5" AB., B2t 5-16" (m2 pr/m2 bk); B3 16-21", 21-48" + CR., oxidized sandy shales at 48" + ; stratified oxidized and semiconsolidated at 84" + ; fragmented hard sandstone from 18" in area.

#13 1,850' W., 100' N of E¼ cor., 0-12" preferred for surface; 12-120" use below surface materials. 8-35% complex side slope near sandy shale and sandstone crests. A/C profile. 108-120" SAR 1.0 SV 25

#14 1,600' W., 600' S of E¼ cor., 0-12" preferred for surface; 12-54" acceptable for surface; 54-120" use for subsurface. 6-12% complex colluvial remnant below sandy shale crests; gullies from 8-35% slope. 0-3" A., AB 3-12"., 12-30" Ccs., isolated profile 60' W shallow to shales.

#15 1,450' N., 1,100' E of S¼ cor., 0-18" preferred for surface; 18-120" for subsurface. 8-35% complex side slopes below sandy shale crest. 0-2" A., 2-9" AB., 9-12" B2 (m2 pr/m2 bk); with lime nettings; 12-18" B3ca., 18" + CR., a small colluvial remnant is less than 15% of the mapping unit; fine salt crystals at 18" +

#16 1,100' S., 100' W of E¼ cor., 0-18" preferred for surface; 18-30" acceptable for surface; 30-60" use for subsurface. 4-8% complex slope alluvial soil below sandy shale crest. Thin plate A over AB to 4"., 4-9" B2 (ml pr/m2 bk); interspersed with shales., 9-18" B3ca. (c3 pr); 18-30" CR., 30-54" C., 54" + C2., carbonaceous shales strongly influencing 18-30" depth.

#17 700' W., 500' N of E¼ cor., 0-18" preferred for surface; 18-30" acceptable for surface; 30-120" use for subsurface. 6-8% complex side slope below sandy shale crest. 0-5" A., 3-8" B2 (2m pr/2m bk) lime nettings; 8-18" B3ca., 18-30" Cca., salt crystals 18" + carbonaceous material at 66" + Depth; SAR; SV 48-66"; 3.2; 32 89-108"; 1.6; 29

#18 1,300' N., 100' W of E¼ cor., 0-18" acceptable for surface; 18-30" use for subsurface. 4-6% complex side slope below sandy shale crest. 0-3" A., 3-6" B12 (ml pr); 6-16" B22t (m2 pr/m2 bk); 16-18" B3ca., 6-18" strongly influenced by carbonaceous shales; Cca 18" + ; salt crystals at 30" + 30-48"; SAR; 1.7 SV 33 54-78"; SAR; 1.9 SV 34

#19 1,300' S., 650' W of NE cor., 0-6" acceptable for surface; 6-120" use for subsurface. 4-6% complex side slope below sand shale crest. A/C profile with shales at 6" or less. Salt crystals at 6" +, carbonaceous at 66" +; shale land with outwash fill varying from 6-18" 0-30"; SAR; 1.1 SV 32 96-108"; SAR; 3.1 SV 36

#20 1,350' S., 800' E of N¼ cor., 0-12" preferred for surface; 12-120" use for subsurface. 4-6% complex side slope below sandy shale and sandstone ledge. 0-3" A., 3-6" B., 6-16" B2t., 16-30" B3ca., 30" + Cca with salt crystals; lime nettings at 12" +; better profile in area. 30-42"; SAR; 4.8 SV 32 54-78"; SAR; 4.9 SV 32 102-120"; SAR; 4.5 SV 28

#21 1,100' E., 1,000' S of N¼ cor., 0-18" preferred for surface; 18-120" acceptable for surface. 2-4% complex colluvial foot slopes below sandy shale ridge. 0-1" A thin crusty; 1-4" AB., 4-9" B12., 9-12" B22t (m2 pr/m2 bk); B3ca 12-18"; 18" + Ccs., lime nettings at 18" +

#22 1,250' W., 100' S of NE cor., 0-24" preferred for surface; 24-90" acceptable for surface. SiL 0-2" A., SiL 2-5" B21; 5-11" B22t (m2 pr/m2 bk); 11-18" B3ca., lime 18-54"; profile is a bench remnant and is not representative.

#23 700' E., 450' S of N¼ cor., 0-18" preferred for surface; 18-78" acceptable for surface. 2-4% complex colluvial foot slope below sandy shale crests. 0-2" A., 2-5" AB., 5-8" B2 (2m pr/m2 bk); 8-18" B3ca (m2 pr); shale fragments at 5" +; lime at 18" +

#24 1,300' W., 950' S of N¼ cor., 0-12" preferred for surface; 12-120" use for subsurface. 8-15% complex side slope below sandy shale and sandstone crests. 0-6" A loam; 6-9" AB., 9-12" B2t., 12-14 B3ca., 14" + CR; salt crystals at 12" +; profile near crest and strongly influenced by shales; not representative.

## EXPLANATION

### LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st
Plant media deficiency
Topographic deficiency
o q — Informative symbols
SURFACE LAYER — Quality, Depth — 2,5 3 2 — 3 7.5
GEOLOGIC MATERIAL — Quality, Depth
SECOND LAYER — Quality, Depth
Divides soil material and nonsoil material

### INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- q Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics
- c Cover

### SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

3 SOIL PROFILE NUMBER

C.L. — 2.8---2.8 EC.mmhos/cm. Bot Est. 8.4-8.0 8.4 pH; 8 Soil-Water Suspension 8.0 pH Soil-CaCl2 Suspension
Lt.C — .55 Hydraulic Conductivity in/hr (Disturbed Samples)
Gr. — 65/24 .....24 Settling Volume

SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gr | Gravel |
| S | Sand |
| LS | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SiL | Silt Loam |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SiCL | Silt Clay Loam |
| SC | Sandy Clay |
| C | Clay |
| SiC | Silty Clay |
| Sh | Shale |
| Sa | Sandstone |
| F | Fine |
| Lt | Light |
| M | Medium |
| H | Heavy |

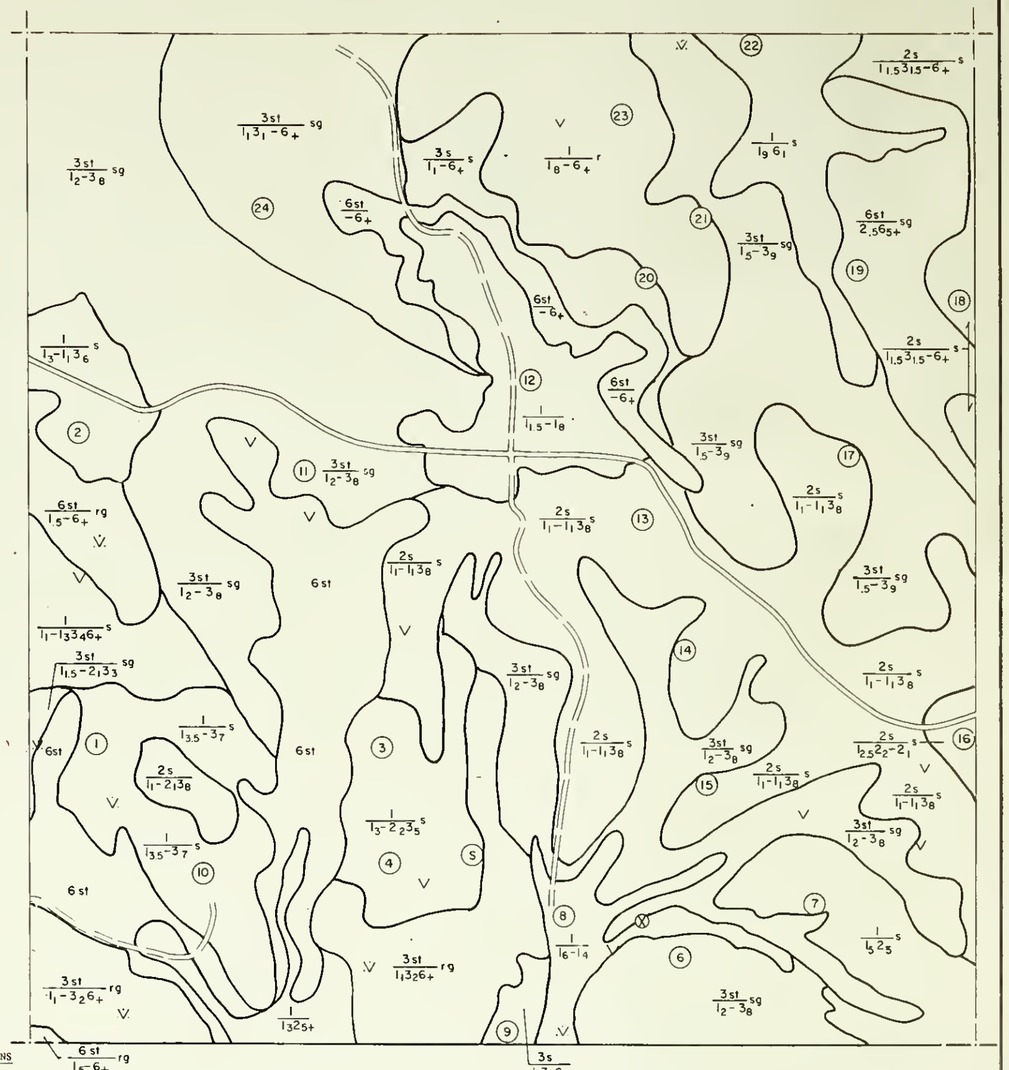
STRUCTURE ABREVIATIONS

Size
- very fine .....vf
- fine .....f
- medium .....m
- coarse .....c
- very coarse ....vc

Grade
- structureless ..0
- weak .....1
- moderate .....2
- strong .....3

Type
- platy .....pl
- prismatic .....pr
- columnar .....cpr
- blocky .....bk
- angular blocky .abk
- subangular blocky .abk
- granular .....gr
- crumb .....cr
- single grain ...sg
- massive .....m

MISCELLANEOUS ABREVIATIONS
- calcic horizon .....Ca
- sodium adsorption-ratio ...SAR
- settling volume ....SV
- cleviced rock.... CR



### CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scoby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS
- Gravel
- Mine

DAMS
- Medium or small

1:4800
SECTION 32, T. 56 N.- R. 72 W.

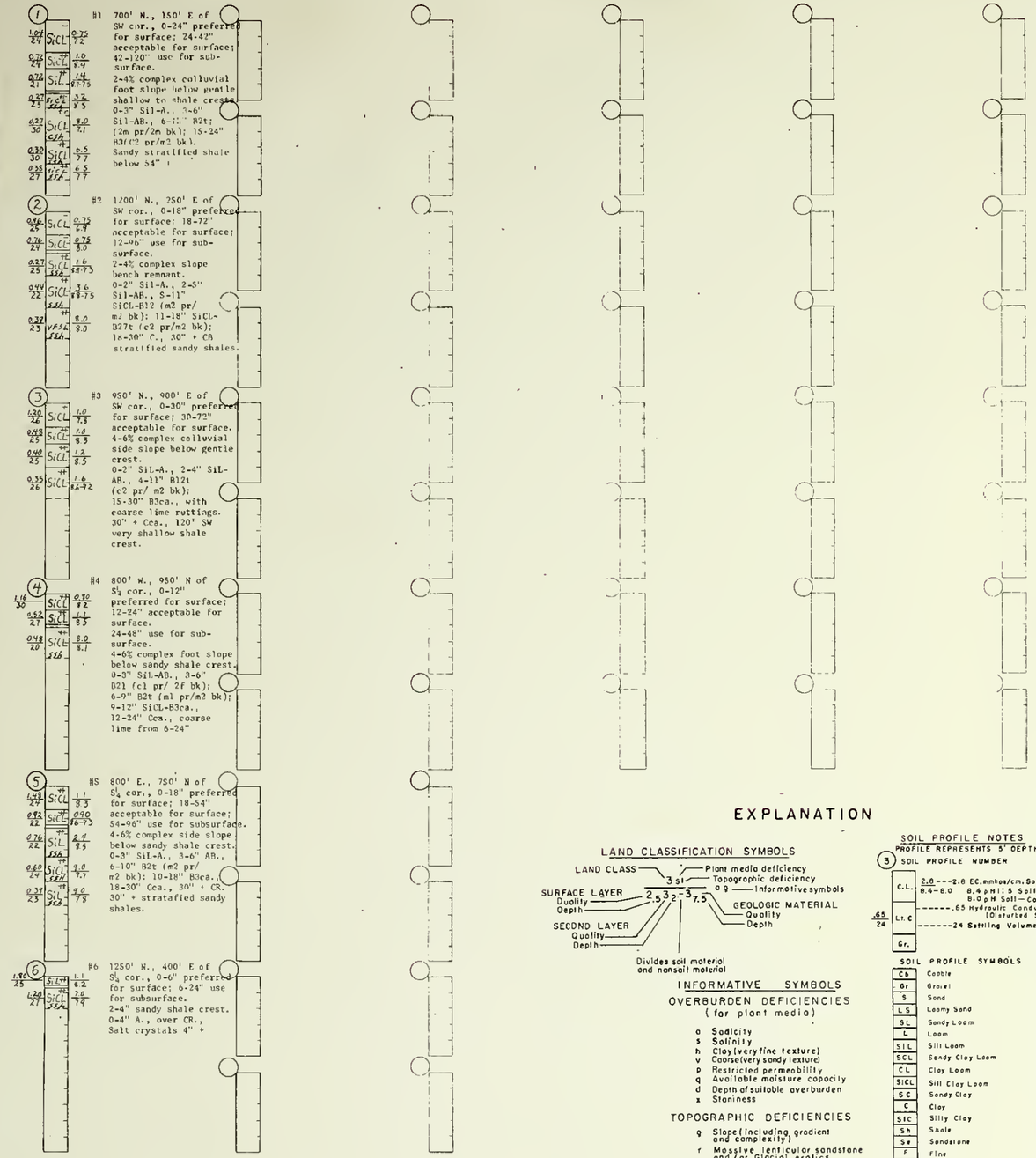
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

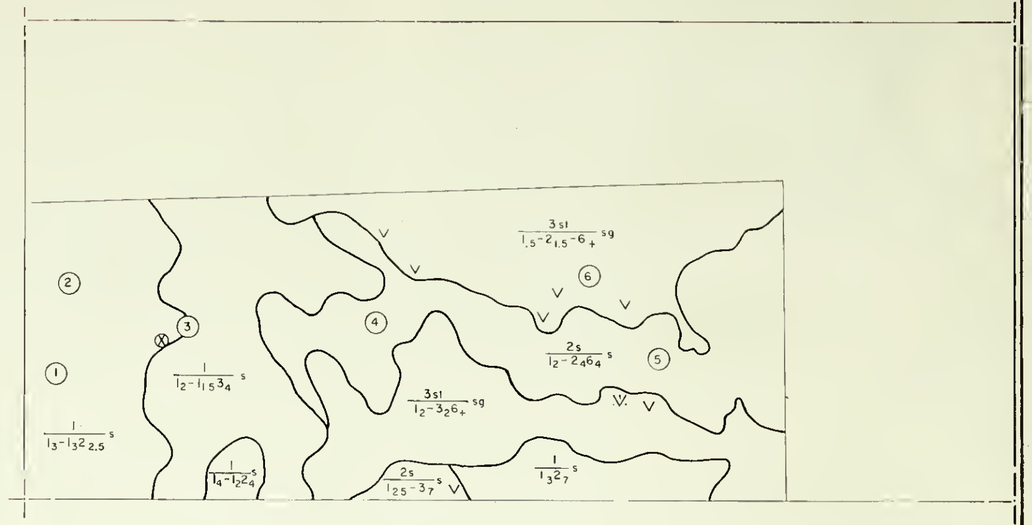
RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING

# DETAIL LAND CLASSIFICATION

SOILS: T. FRICHTL — SUBMITTED
DRAWN: L. E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — JUNE 1977 — 1305-600-142




## EXPLANATION

### LAND CLASSIFICATION SYMBOLS




### INFORMATIVE SYMBOLS

**OVERBURDEN DEFICIENCIES** (for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- z Stoniness

**TOPOGRAPHIC DEFICIENCIES**

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics
- c Cover

### SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

3 SOIL PROFILE NUMBER

C.L. — 2.0---2.8 EC.mmhos/cm. Sat Ext.; 8.4-8.0 8.4 pH 1:5 Soil—Water Suspension; 8.0 pH Soil—CaCl2 Suspension
Lt. C — .65 / 24 ------.65 Hydraulic Conductivity in/hr. (Disturbed Samples); ------24 Settling Volume
Gr.

### SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gr | Gravel |
| S | Sand |
| LS | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SIL | Silt Loam |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SICL | Silt Clay Loam |
| SC | Sandy Clay |
| C | Clay |
| SIC | Silty Clay |
| Sh | Shale |
| Ss | Sandstone |
| F | Fine |
| Lt | Light |
| M | Medium |
| H | Heavy |

### STRUCTURE ABREVIATIONS

Size: very fine .....vf; fine .....f; medium .....m; coarse .....c; very coarse ....vc

Grade: structureless ..0; weak .....1; moderate .....2; strong .....3

Type: platy .....pl; prismatic .....pr; columnar .....cpr; blocky .....bk; angular blocky .abk; subangular blocky .sbk; granular .....gr; crumb .....cr; single grain ...sg; massive .....m

MISCELLANEOUS ABREVIATIONS: calcic horizon .....Ca; sodium adsorpation-ratio ...SAR; settling volume .....SV; creviced rock... CR

### CONVENTIONAL AND SPECIAL MAP SYMBOLS

**LAND FEATURES**

- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock-clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

**WATER FEATURES**

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

**PITS**

- Gravel
- Mine

**DAMS**

- Medium or small

N

1:4800

SECTION 24, T 56 N.-R. 73 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING

# DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL SUBMITTED
DRAWN L. E. ALLSOP RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA JUNE 1977 1305-600-143

#1 250' S., 200' W of N¼ cor., 0-18" preferred for surface; 18-36" acceptable for surface; 30-120" use for subsurface. 4-8% complex colluvial side slope below sandy shale crest. 0-2" SiL-A., 2-5" AB., 5-10" B2t (m2 pr/m2 bk)., 10-18" B3ca., 18-30" Cca. Lime at 60" +

#2 300' E., 50' S of N¼ cor., 0-18" preferred for surface; 18-120" acceptable for surface. 4-6% complex colluvial side slope below gentle crest. 0-2" SiL-A., 2-6" B2t (m2 pr/m2 bk); 6-12" B3ca., 12" + Cca., with lime accumulations. 48-72" shale influence.

#3 1,400' S of N¼ cor., 0-18" preferred surface material; 18-30" acceptable for surface; 30-120" use for subsurface. 6-8% side slope below sandy shale crest. 0-2" SiL-A., 2-5" AB., 5-10" B2(m2 pr/ m1 bk); 10-15" B3ca. CR 15" + ; Sand at 90" +

#4 1,300' E., 450' S of NW cor., 0-12" preferred for surface; 12-72" acceptable for surface; 72-108" use for subsurface. 4-6% complex side slope below a gentle crest. 0-3" A., 3-12" B2t (m2 pr/m2 bk); 12-18" Cca., 18" + CR., roots to 30" ; semiconsolidated sandy shales at 72"

#5 1,050' W., 800' S of N¼ cor., 0-18" preferred for surface; 18-120" acceptable for surface. 2-4% alluvial swale below gentle crests. 0-2" loam A., 2-4" AB., 4-14" B2t (m2 pr/m2 bk); 14-36" B3 with scattered weakly calcareous spots. Lime to 72"

#6 950' S., 200' E of NW cor., 0-18" preferred for surface; 18-30" acceptable for surface; 30-60" use for subsurface. 4-6% complex side slope near top of gentle crest. A/C moderately lime over sandy shales. 30-48" SAR 8.5, SV 27

#7 300' S., 250' E of NW cor., 0-18" preferred for surface; 18-48" acceptable for surface; 48-108" use for subsurface. 2-4% side slope below gentle crest. 0-3" A., 3-8" B2 (m2 pr/m2 bk); 8-18" B3ca., 18" + CR., roots to 48"; salt crystals at 72" + 18-36" SAR 6.3 SV 31 96-108" SAR 2.0 SV 37

#8 1,150' N., 550' E of N¼ cor., 0-18" preferred for surface; 18-42" acceptable for surface; 42-120" use for subsurface. 2-4% gentle side slope below shale crests. 0-2" A., 2-4" AB., 4-9" B2., 9-12" B3ca., 12-18" Cca., 18" + CR., salt crystals in semiconsolidated sandy shales at 42" + 42-60" SAR 1.3 SV 30

#9 850' E., 650' N of N¼ cor., 0-30" preferred for surface; 30-120" acceptable for surface. 2-4% complex colluvial side slope shaley gentle crests. 0-3" A., 3-5" AB., 5-10" B12 (2m pr/2m bk); 10-18" B22t (2c pr/ 2m bk); 18-30" B3., 30" + Cca., 72" + CR., roots to 30" ; sandstone at 30" in area.

#10 200' E., 50' N of W¼ cor., 0-18" preferred for surface; 18-48" acceptable for surface; 48-120" use for subsurface. 2-4% complex side slope below gentle crest. 0-4" A., 4-9" AB., 6-14" B2t (2m pr/2m bk); 14-18" B3 (2m pr/2m bk); 18" + Cca., 48" + CR., roots to 21"

#11 1,000' E., 100' S of W¼ cor., 0-12" preferred for surface; 12-48" acceptable for surface; 48-120" use for subsurface. 4-6% complex side slope below gentle shallow crest. 0-3" A., 3-7" AB., 7-10" B3ca., 10" + CR., roots to 24" ; semiconsolidated shale at 48" +

#12 750' S., 100' E of W¼ cor., 0-12" preferred for surface; 12-36" acceptable for surface; 36-120" subsurface materials. 2-4% complex foot slope below gentle crests. A/C profile with stratafied shales at 12" + 48-66" SAR 1.1 SV 33

#13 1,100' S., 600' E of W¼ cor., 0-30" preferred for surface; 30-120" use for subsurface. 2-4% complex side slope near gentle crest. 0-2" SiL-A., 2-5" SiL-AB., 5-9" B12 (m1 pr/m2 bk); B22t (c2 pr/m2 bk); thin clay skins; 18-27" B3; Cca., 27" +

#14 950' N., 550' E of SW cor., 0-18" preferred for surface; 18-120" use for subsurface. 2-4% complex side slope below shallow gentle crest. 0-3" A., 3-8" B2t (c2 pr/m2 bk); 8-18" B3ca (c1 pr/ m2 bk); Cca., 18" + ; sandy shales 30" + ; roots to 30"

#15 350' E., 100' N of SW cor., 0-12" preferred for surface; 12-54" acceptable for surface; 54-66" use for subsurface. 4-6% complex side slope below gentle crest. 0-3" A., 3-5" B2; 5-10" B3ca., 10" + Cca.

#16 700' W., 400' N of S¼ cor., 0-18" preferred for surface; 18-24" acceptable for surface. 4-6% complex side slope below sandy shale crest. 10-30% slopes in area. 0-3" A., 3-6" B., 6-9" B2t; 9-14" B3ca., C. 14" + ; baked rock outcrops in area.

#17 1,400' N., 400' W of S¼ cor., 0-18" preferred for surface; 18-42" acceptable for surface; 42-120" use for subsurface. 6-8% complex colluvial side slope below sandy shale crest. 0-3" A., 3-7" B2; 7 7-18" B3ca., hard formation at 42" + ; roots to 42" 102-120" SAR 3.5 SV 32

#18 2,000' E., 350' N of W¼ cor., 0-18" preferred for surface; 18-54" use for subsurface. 4-6% complex side slope below gentle crest. 0-3" A., 3-7" B21t (m2 pr/m2 bk); 7-14" B22t (c2 pr/c2 bk); 14-18" B3ca.

#19 2,100' E., 500' S of W¼ cor., 0-12" preferred for surface; 12-120" acceptable for surface. 4-6% complex side slope near shallow gentle crest. A/C profile with hard shale at 30"; lime to surface. Thin carbonaceous deposit at 42" + ; roots to 30"

#20 1,600' W., of 100' N of E¼ cor., 0-12" preferred for surface; 12-120" for subsurface. 6-15% complex side slope below gentle crest. 0-1" A., 1-4" AB., 4-7" B21t (m2 pr/m2 bk); 7-12" B3 (c2 pr/m2 bk); reddish-brown soil over shales; salt crystals at 24" + ; grayish shales 72-108"

#21 1,300' S., 750' E of N¼ cor., 0-18" preferred for surface; 18-96" acceptable for surface. 2-4% complex colluvial foot slope below sandy shale crest. 0-1" A., 1-4" AB., 4-7" B2t (m2 pr/m2 bk); 7-18" B3ca (c2 pr/ c2 bk).

#22 1,000' W., 750' N of E¼ cor., 0-30" preferred for surface; 30-120" acceptable for surface. 8-35% complex foot slope below baked rock crests. 0-3" A., 3-12" B12 (m1 pr/m2 bk); 12-30" B3 (c2 pr/c2 bk); 30" + Cca. Baked rock throughout profile. Upper slopes very shallow. Profile represents 25% of area or less.

#23 800' S., 850' W of NE cor., 0-24" preferred for surface; 24-48" acceptable for surface; 48-120" use for subsurface. 4-6% complex colluvial foot slope below baked rock crest. 0-1" A., 1-5" AB., 5-12" B2t (2m pr/ 2f bk); 12-24" B3ca.; salt crystals 29 at 48" + ; brown soil becoming reddish-brown at 48" +

#24 700' W., 300' S of E¼ cor., 0-12" preferred for surface; 12-36" use for subsurface. 4-6% complex side slope below gentle crest. 0-4" A., 4-8" B21 8" + Cca., shaley C2 at 12" + with salt crystals; some moderately deep profiles in area.

#25 1,300' W., 450 S of E¼ cor., 0-18" preferred for surface; 18-60" acceptable for surface; 60-90" use for subsurface. 4-6% complex crest. A/C profile with surface S" A horizon. FSL., 5-18" FSL/Loam; stratafied shales. 60-78" SAR 2.6 SV 32

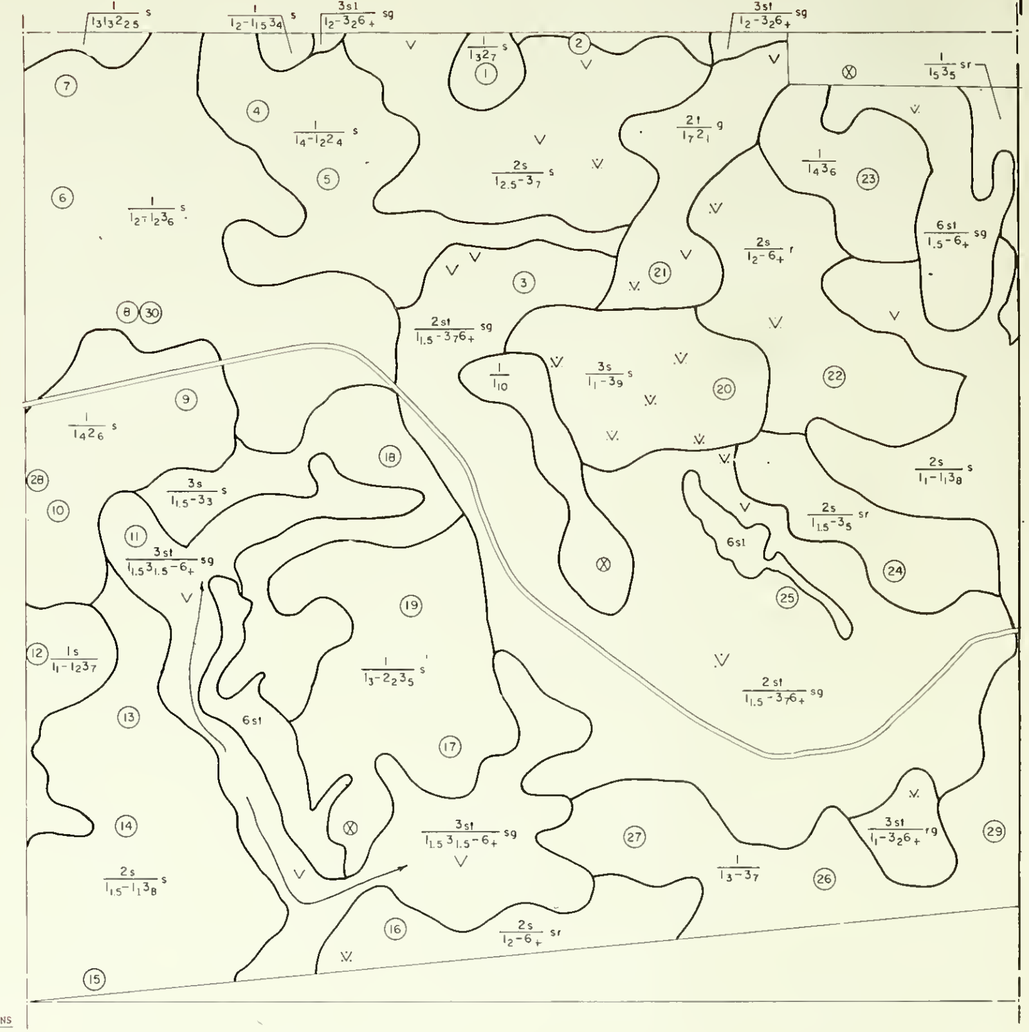
#26 1,100' W., 650' N of SE cor., 0-24" acceptable for surface; 24-120" acceptable for surface. 4-6% complex side slope below gentle crest. 0-4" A., 4-11" B12t (m2 pr/m2 bk); 11-16" B22t (c2 pr/ m2 bk); 16-24" B3ca., 24" + CR., roots to 24" 48-72" SAR 0.7 SV 35

#27 900' N., 600' E of S¼ cor., 0-18" preferred for surface; 18-66" acceptable for surface; 66-120" use for subsurface. 4-6% complex side slope below shallow gentle crests. 0-3" A., 3-8" B12 (m2 pr); 8-14" B22 (c2 pr/m2 bk); 14-18" B3ca., 18" + Cca., roots restricted at 30" ; stratafied sandy shales.

#28 200' N., 50' E of W¼ cor., 0-24" preferred for surface; 24-120" acceptable for surface. 2-4% complex colluvial foot slope below gentle shallow sandy shale crests. See Master-Site No. for profile description. 36-54" 10.4% lime by weight.

#29 900' N., 150' W of SE cor., 0-18" preferred for surface; 18-30" acceptable for surface; 30-120" use for subsurface. 4-6% complex side slope below gentle crest. 0-1" SiL-A., 1-2" SiL-AB., 2-6" B21t (m2 pr/m2 bk) SiCL., 6-10" B22t (c2 pr/ m2 bk); 10-18" B3ca (c1 pr/m2 bk); 18-30" Cca., 0-12" with 5.4% lime by weight.

#30 1,100' N., 700' E of W¼ cor., 0-12" acceptable for surface; 12-120" use for subsurface. 2-4% complex moderately deep residual soil below a gentle shallow sandy shale crest. 0-2" A., 2-8" AC., 8-33" SiCL., Cca., 33" + IIC; 42" + salt crystals. 6-30" with 14.0% lime weight. 42-60" SAR 0.8 SV 29



## EXPLANATION

### LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 s1 — Plant media deficiency; Topographic deficiency; 0 g — Informative symbols

SURFACE LAYER — Quality — Depth: 2-5

SECOND LAYER — Quality — Depth: 3 2 -3 7.5

GEOLOGIC MATERIAL — Quality — Depth

* Divides soil material and nonsoil material

### INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Salicity
- s Salinity
- h Clay(very fine texture)
- v Coarse(very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope(including gradient and complexity)
- r Massive (lenticular sandstone and/or glacial erratics
- c Cover

### SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

3 SOIL PROFILE NUMBER

C.L. — 2.8---2.8 EC.mmhos/cm. Sat. Ext.; 8.4-8.0 8.4 pH 1:5 Salt-Water Suspension; 8.0 pH Salt—Ca Cl2 Suspension

.65/24 Lt.C — .65 Hydraulic Conductivity, in/hr (Disturbed Sample); 24 Settling Volume

Gr.

SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gi | Gravel |
| S | Sand |
| L S | Loamy Sand |
| S L | Sandy Loam |
| L | Loam |
| Si L | Silt Loam |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SiCL | Silt Clay Loam |
| SC | Sandy Clay |
| C | Clay |
| SiC | Silty Clay |
| Sh | Shale |
| Sa | Sandstone |
| F | Fine |
| Lt | Light |
| M | Medium |
| H | Heavy |

STRUCTURE ABREVIATIONS

Size: very fine .....vf; fine .....f; medium .....m; coarse .....c; very coarse ....vc

Grade: structureless ..0; weak .....1; moderate .....2; strong .....3

Type: platy .....pl; prismatic .....pr; columnar .....cpr; blocky .....bk; angular blocky .abk; subangular blocky .sbk; granular .....gr; crumb .....cr; single grain ...sg; massive .....m

MISCELLANEOUS ABREVIATIONS

calcic horizon .....Ca; sodium adsorption-ratio ...SAR; settling volume .....SV; crevicked rock.... CR

### CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES: Blowout; Clay spot; Gravelly spot; Gumbo, slick or scaby spot (sodic); Dumps and similar nonsoil areas; Rock outcrop(includes shale and sandstone); Baked rock-clinker (local name scoria); Slide or slip(to point upslope); Stony spot, very stony spot; Greasewood

WATER FEATURES: Marsh or swamp; Spring; Well, artesian; Well, irrigation; Well spot

PITS: Gravel; Mine

DAMS: Medium or small

1:4800

SECTION 25, T. 56 N.-R. 73 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

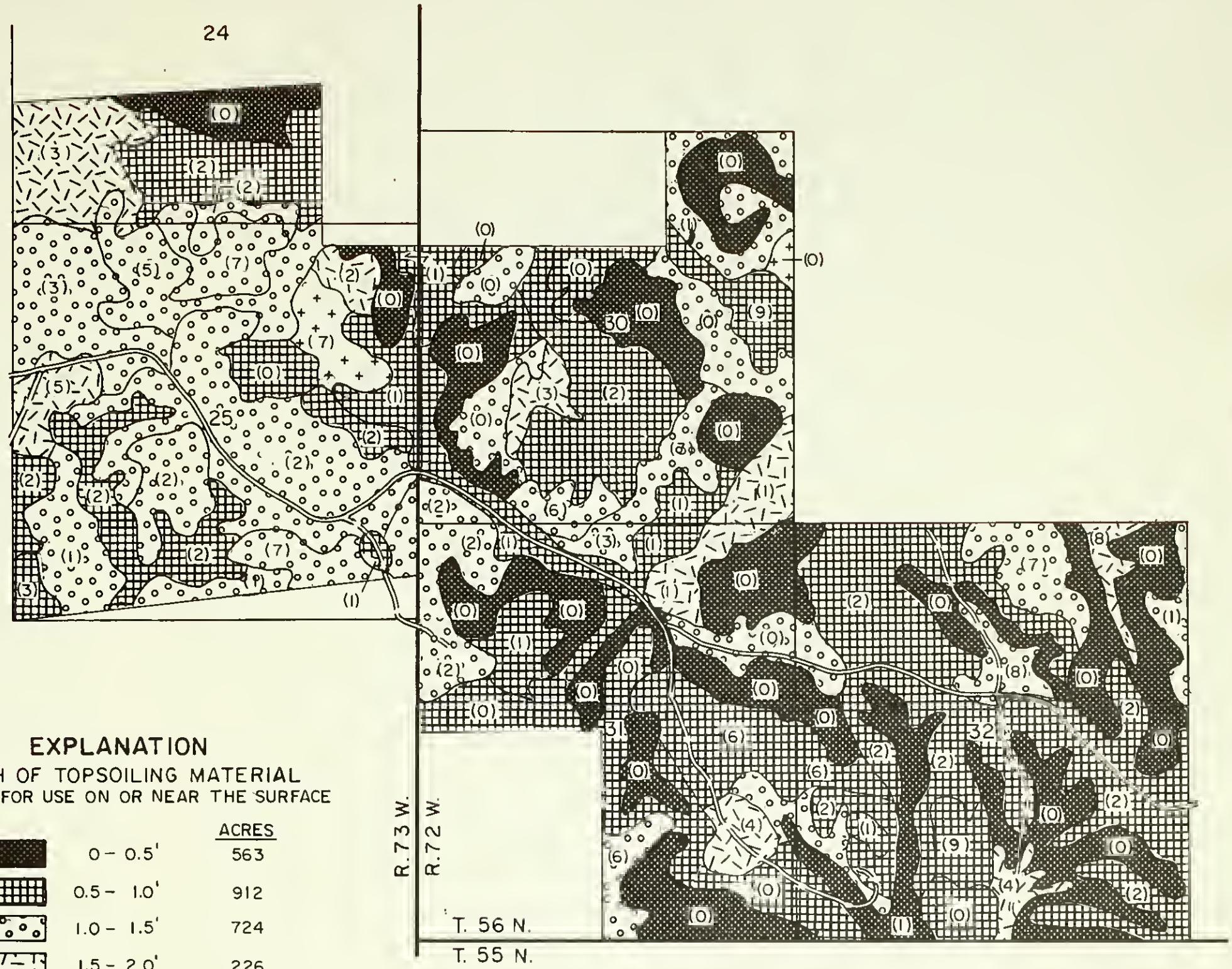
RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING

# DETAIL LAND CLASSIFICATION

SOILS J. FIECHTL ..... SUBMITTED .....
DRAWN L.E. ALLSOP ..... RECOMMENDED .....
CHECKED ..... APPROVED .....

BILLINGS, MONTANA — JUNE 1977 — 1305-600-144




## EXPLANATION

DEPTH OF TOPSOILING MATERIAL
MATERIAL FOR USE ON OR NEAR THE SURFACE

| | | ACRES |
|---|---|---|
| | 0 – 0.5' | 563 |
| | 0.5 – 1.0' | 912 |
| | 1.0 – 1.5' | 724 |
| | 1.5 – 2.0' | 226 |
| | 2.0 – 2.5' | 31 |

SURFACE MATERIALS
PREFERRED & ADDITIONAL
1 – 1.5' (2')

Section 30, 31, 32, T. 56 N. - R. 72 W.
Section 24, 25, T. 56 N. - R. 73 W.
1:24 000

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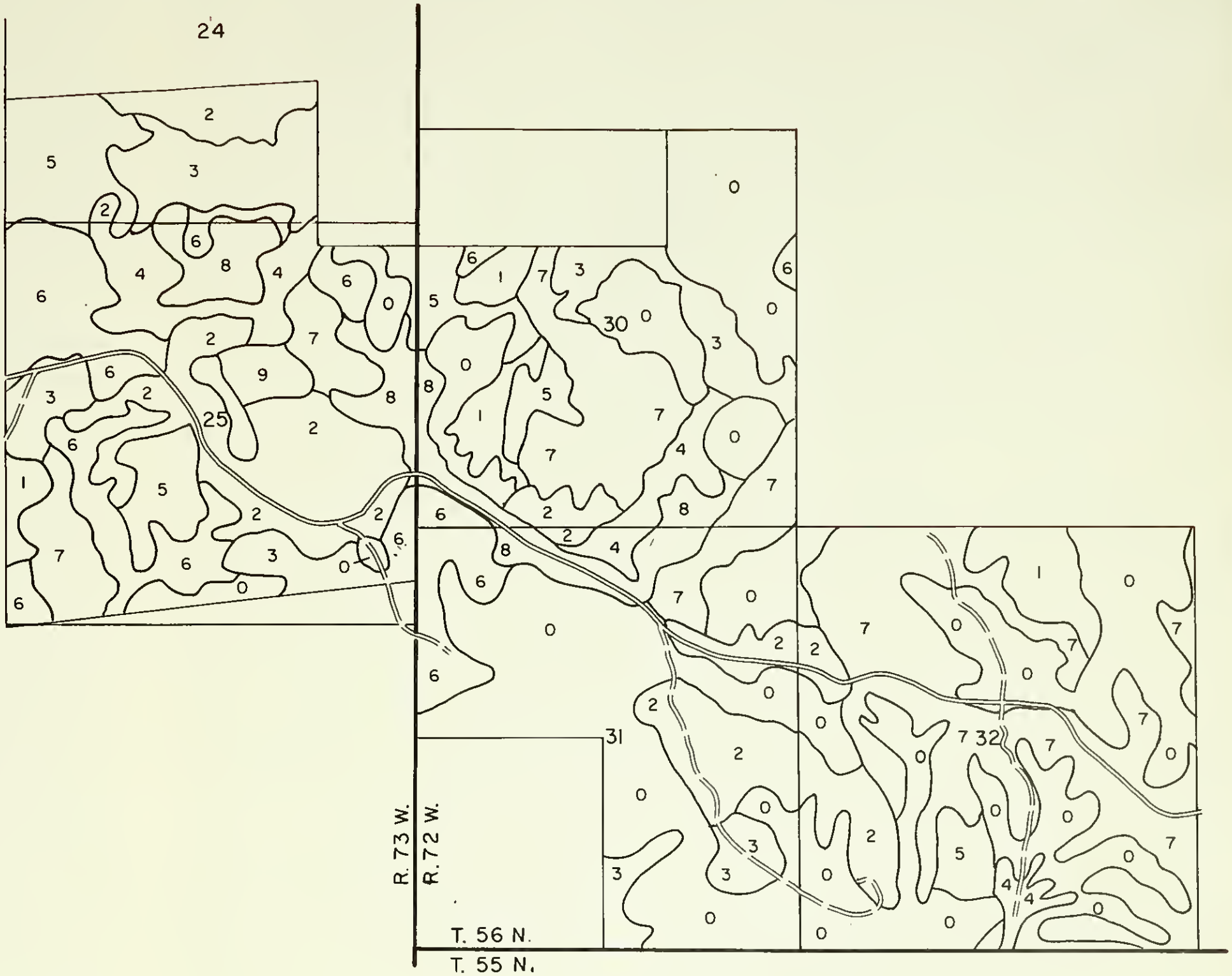
# SURFACE MATERIAL MAP

LANDS HB WARO SUBMITTED
DRAWN L E ALLSOP RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MAY, 1977 1305-600-138




Section 30,31,32, T.56 N.- R.72 W.
Section 24,25, T.56 N.- R.73 W.
1: 24000

DEPTH OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2 1/

1/ ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL SHOWN ON PLATE – (FACING PAGE)

NOTE
This material may be slowly permeable, saline, moderately sodic or clay rich, but is well suited for placement as indicated. It is not suitable for use at or near the surface without modification; leaching, mixing, etc.

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WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING
**SUB HORIZON MATERIAL MAP**

LANDS H.B. WARD SUBMITTED
DRAWN L.E. ALLSOP RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MAY, 1977 1305-600-139

the soil organic matter is contained in these horizons. Typically, the A horizon is only 2 to 6 inches thick over a weakly developed B horizon. Therefore, selective stripping of the A horizon from the B and/or C horizons appears impractical. However, mixing of the surface horizons should not appreciably change the quality of the material.

Soluble salts have been leached to a depth of about 24 inches in deep, loamy soils with good permeability. This generally includes the A, B, and part of the C horizons of most soils in this study area. Soluble salts often remain near the surface in shallow A-C soils, saline-sodic soils, and seep areas. Seed germination and plant maturation may be severely restricted in saline and/or sodic soils. Therefore, soil materials with high levels of soluble salts or exchangeable sodium should be placed below the plant rooting zone in reconstructed profiles.

The use of fine-textured (clay-rich) soil as topsoiling material should be avoided. Precipitation infiltrates this material at a slow rate; therefore, an increase in runoff and surface erosion would occur in the reclaimed area. These factors could severely limit the potential for successful revegetation.

The use of coarse-textured (sandy) soil as topdressing material should also be avoided. Seed germination and plant development would be restricted in this material due to its low moisture retention and fertility. Also, this material may be highly susceptible to erosion.

The detailed land classification maps, Plates 26 through 30, describe the areal distribution and suitability of all land classes in this study area. The land class symbols record the depth and quality of the soil and indicate the major deficiencies affecting its suitability for use as plant media.

## Bedrock Suitability

A systematic evaluation was made of the bedrock materials described in Plates 10 through 22, Appendix B. The applicable portions of the Land Suitability Specifications (Table 18) provided criteria for the evaluation of these materials.

Bedrock core samples were collected and analyzed in the laboratory and greenhouse utilizing the same procedures used to analyze the soil samples. Results of the laboratory analyses performed on the core samples are listed on the bottom of Plates 10 through 22, Appendix B. Simulated weathering was applied to selected samples to give some indication of how the materials would break down when exposed to the weather. The results from these tests and the laboratory analyses provided the basic data used in evaluating bedrock suitability for revegetation.

Although similar criteria were used for both the land suitability survey and the bedrock core evaluation, different suitability classes were assigned to the core materials. These classes relate primarily to the quality of the bedrock materials for use as plant media in revegetation. The classes are "suitable," "limited suitability," and "unsuitable." The suitable class

corresponds to Class 1 and the higher quality Class 2 materials in the land suitability survey; the limited suitability class includes the less desirable Class 2 materials and Class 3; and the unsuitable class is equivalent to Class 6. The suitability of core sample materials in the White Tail Butte Study Area is indicated in Table 20, Appendix D. Overall, 7.1 percent of the bedrock materials overlying the Canyon coalbed in this study area were determined to be "suitable" for use as plant media, 35.9 percent were of "limited suitability," and 57 percent were "unsuitable." The most suitable materials seem to be uncemented silty or clayey sandstones that lie reasonably close to the surface (0 to 50 feet). Materials comprising the limited suitability class are primarily soft silty or sandy shales and uncemented siltstones and sandstones. Unsuitable materials are composed mainly of cemented sandstones and siltstones and carbonaceous shales.

Because the type and quality of bedrock materials are quite diverse, the physical and chemical properties important to their use as plant media cannot be projected accurately over a wide range of conditions. Therefore, the quality determination of the core materials applies only to the specific site where each core was drilled. No attempt was made to project the data to adjacent areas. Also, the ease of separating and stockpiling bedrock materials for resurfacing was not a factor in the evaluation.

Although the consolidated bedrock in the White Tail Butte Study Area should break down readily upon weathering, it is generally unsuitable for use as revegetative media at or near the surface in reconstructed profiles. Notable deficiencies of the bedrock materials often include one or more of the following: fine texture (i.e., shale), salinity, sodicity, slow permeability, instability, and erodibility.

All geologic cores from the bedrock were moderately saline between 5 and 10 feet. This agrees with data from over 39 soil borings. Some of this material is moderately permeable and, if it is needed for subsurface material (1.5 to 3 feet) in reconstructed profiles, the soluble salts should be removed by natural precipitation within a few years. Clay-rich layers are saline and relatively impermeable. They are unsuited for use in the plant root zone.

The bedrock below 15 feet is usually nonsaline and nonsodic; however, it often contains a large amount of swelling clay. In shrink/swell tests the volume of material increased by 30 to 60 percent. It is unstable and slowly permeable. These soil-related deficiencies would increase the hazard to new seedlings from erosion and the reduced availability of soil moisture. Other adverse effects of placing this material on the surface would be a reduced vegetative cover and an increased contribution of sediment to receiving streams. Therefore, this material should be placed below the average rooting depth of plants used for revegetation.

## Soil Inventory

This section provides additional data on the soils occurring in the White Tail Butte Study Area. This data is derived primarily from soil survey information compiled by the Soil Conservation Service (U.S.D.A.).

Included in this section are the following:

1. A Soils Map of the White Tail Butte Study Area showing the soil series/associations mapped by the Soil Conservation Service - Plate 33, Appendix D,

2. Interpretive ratings for selected soil uses - Table 21, Appendix D,

3. Soil Profile Descriptions (BLM Form 7310-9) and Erosion Evaluations (BLM Form 7310-12) - Exhibit 2, Appendix D,

4. Descriptions of the SCS mapping units shown on the Soils Map, Plate 33, Appendix D.

In general, the taxonomic classification of soils in this study area is divided between Aridisols and Entisols. Aridisols occupy about 41 percent of the study area and Entisols occur on approximately 51 percent of the area.

The following tabulation lists the acreage and percentage of the study area occupied by each mapping unit.

| Map Symbol | | | | |
|---|---|---|---|---|
| BLM | SCS | Name | Acres | Percent of Area |
| 024-025 | BiBd | Bidman-Briggsdale | 25 | 1 |
| 024 | Bi | Bidman | 6 | 1 |
| 012 | Cu | Cushman | 44 | 2 |
| 012-037 | CuSt | Cushman-Stoneham | 146 | 6 |
| 012-034 | CuWf | Cushman-Worf | 110 | 5 |
| 026 | Ds | Dillingson | 44 | 2 |
| 027-012 | FcCu | Fort Collins-Cushman | 158 | 6 |
| 035-029 | HmSh | Hamstone-Shingle | 40 | 2 |
| 028-033 | SeWx | Sear-Wibaux | 369 | 15 |
| 029-036 | ShRo | Shingle-Rock outcrop | 35 | 2 |
| 029-031 | ShSl(gl) | Shingle-Samsil (gullied) | 590 | 24 |
| 029-032 | ShTd(rl) | Shingle-Thedaland (rolling) | 450 | 18 |
| 029-034 | ShWf | Shingle-Worf | 148 | 6 |
| 06 | Te | Terrace Escarpment | 13 | 1 |
| 033-029 | Wx(ro) | Wibaux (rock outcrop) Shingle | 278 | 11 |

## Description of Mapping Units

This subsection includes a description of each mapping unit shown on the Soils Map, Plate 33, Appendix D. It should be noted that some mapping units are composed of members other than soil series. For example, rock outcrop is a land type and does not belong to a soil series.

A description of the soil profile - the sequence of layers beginning at the surface and extending to a depth beyond which the roots of most plants do not penetrate - typical of each soil series is included within each mapping unit description. Unless otherwise noted, all colors described are for dry soils.

Mapping Unit 024 - Soil 8024 in this mapping unit represents less than 1 percent of the study area. The areal distribution and acres in each mapping unit are shown on Plate 33, Appendix D. This soil formed in well drained, medium-textured alluvium which is more than 4.9 feet deep. It is most commonly found on local alluvial fans and footslopes. The parent material in this area is interbedded sandstone and shale. Slope gradients are usually less than 6 percent.

Typically, the surface layer is a friable, grayish brown loam or silt loam which rests on a dark grayish brown, prismatic, silty clay B horizon. Below this, the substratum is a calcareous grayish brown, silty clay loam. This soil is usually nonsaline and nonsodic above 4.9 feet, but may be moderately to highly saline below this depth.

Water enters the surface layer at a moderate rate, but movement through the profile is slow. This causes the soil to be slightly erosive and droughty on the steeper slopes. This soil is a member of the fine, montmorillonitic, mesic family of Ustollic Paleargids.

Mapping Unit 024-025 - This soil association represents about 1 percent of the study area. Soil 8024 is very similar to its description in mapping unit 024.

Soil 8025 is in this mapping unit and may be one of the minor soils in mapping units 012, 012-030, and 012-034. This moderately deep, residual soil formed in interbedded sandstone and shale. The surface is a friable, light gray sandy loam. The B horizons consist of a friable clay loam that abruptly changes to a sticky, plastic, silty clay. Below this, the substratum is a light grayish brown, calcareous material that grades into weathered, calcareous shale. Depth to the shale varies from 1.6 to 3.3 feet. This soil is a member of the fine, montmorillonitic, mesic family of Ustollic Paleargids.

Infiltration, permeability, and moisture retention are similar to soil 8024. Depth to moderate or highly saline material is about 2 feet. The slope gradients range from 0 to 6 percent.

Mapping Unit 012 - Soil 8012 in this mapping unit represents 2 percent of the study area. It is also a major soil in the following associations: 012-030, 012-034, and 027-012.

Soil 8012 is a moderately deep, residual soil formed in material weathered from interbedded sandstone and silty shale. It is most common on rolling uplands and upper footslopes below tabular divides. Surface relief consists of relatively smooth slopes of 3 to 6 percent.

The surface layer is a light brownish gray, friable loam. Typically, the subsoil is brown, slightly sticky and slightly plastic, very fine sandy clay loam with prismatic structure. The C horizons are calcareous, very fine sandy clay loam. Depth to shale is about 2 feet. This soil is a member of the fine-loamy, mixed, mesic family of Ustollic Haplargids.

Precipitation enters and moves through this soil at a moderate rate. About 2 inches of moisture per foot are available for plant use. The soil mantle is nonsaline and nonsodic; the underlying shale is usually moderately to highly saline and nonsodic.

Mapping Unit 012-030 - This soil association represents about 6 percent of the study area. Soil 8012 is very similar to its description in mapping unit 012.

Soil 8030 is a deep colluvial soil formed in material eroded from interbedded sandstone and shale. Typically, this soil has a very friable, granular, loam surface horizon; a thin clay loam B2t horizon with prismatic and subangular blocky structure; and medium-textured, calcareous C horizons in which secondary calcium carbonate has accumulated. This soil is a member of the fine-loamy, mixed, mesic family of Ustollic Haplargids.

This soil association is commonly found on rolling uplands and on footslopes below tabular divides. The shallower 8012 soil occurs on the upper slopes and perimeter of the deeper 8030 soils. Slope gradients range from 3 to 12 percent.

Mapping Unit 012-034 - This soil association comprises about 5 percent of the study area. Soil 8012 is very similar to its description in mapping unit 012.

Soil 8034 is a shallow residual soil formed in weathered, interbedded siltstone and shale. Typically, this soil has a grayish brown, very friable, loam A horizon; a brown, prismatic, clay loam B2t horizon; and a light yellowish brown, prismatic and subangular blocky, clay loam $B3_{ca}$ horizon over interbedded calcareous shale and siltstone. This soil is a member of the fine-loamy, mixed, mesic, shallow family of Ustollic Haplargids.

This soil association is commonly found on moderately rolling uplands. The shallower 8034 soil occurs on narrow ridges, steeper slopes below ridge crests, and near bedrock outcrops. The deeper 8012 soil is on the lower slopes and protected tracts below deeper soils in adjacent mapping units. Slopes are often irregular and slightly complex. Surface gradients range from 6 to 15 percent.

Mapping Unit 026 - Soil 8026 in this mapping unit represents about 2 percent of the study area. The well drained soil formed in material weathered from baked rock (locally called scoria or clinker). It is found in association with baked rock outcrops and baked rock capped buttes in the uplands. Surface gradients range from 2 to 6 percent.

Typically, this soil has a friable, granular, light brown, very fine sandy loam A1 horizon; a prismatic, light reddish brown, very fine sandy clay loam B1 horizon; a reddish brown, clay loam, prismatic and subangular blocky B2t horizon; and light reddish brown, gravelly loam $B3_{ca}$ horizons. Below this is a pink, gravelly fine sandy loam, massive, calcareous $C_{ca}$ horizon. This soil is a member of the fine-loamy, mixed, mesic family of Ustollic Haplargids.

Mapping Unit 027-012 - This soil association comprises about 6 percent of the study area. Soil 8012 is very similar to its description in mapping unit 012.

Soil 8027 is a deep residual soil formed in material weathered from sandstone and shale. Typically, this soil has a friable, granular A horizon; a B2t horizon with prismatic to subangular blocky structure; and medium-textured, calcareous C horizons in which visible secondary calcium carbonate has accumulated. This soil is a member of the fine-loamy, mixed, mesic family of Ustollic Haplargids.

This soil association is on the relatively smooth to gently rolling uplands. Surface gradients usually range from 3 to 6 percent with a few slopes to 12 percent. Soil 8012 is most commonly found near the crests of weak ridges and undulations.

Mapping Unit 035-029 - This soil association represents about 2 percent of the study area. The mapping unit consists of gently to steeply sloping uplands with a few bedrock outcrops. Generally, the surface gradient ranges from 6 to 15 percent. Both soils formed in material weathered from interbedded shales.

Typically, soil 8035 has a friable, granular, light yellowish brown A horizon; a sticky and plastic, yellowish brown, clay loam B2t horizon; and a calcareous, yellowish brown, clay loam $B3_{ca}$ horizon. Below this, a calcareous, pale brown, loam $C_{ca}$ horizon extends to the shale contact. Depth to the shale is 1.6 to 2.6 feet. This soil is a member of the fine-loamy, mixed, mesic Ustollic Haplargids.

Typically, soil 8029 has a light brownish gray, very friable, calcareous, clay loam A horizon. Below this, light yellowish brown, calcareous, clay loam C horizons extend to the shale contact. Depth to the shale is 0.8 to 1.6 feet. This soil is a member of the loamy, mixed, mesic, shallow family of Ustic Torriorthents.

Precipitation readily infiltrates the permeable A horizon of these soils. However, internal water movement is restricted by the fine-textured C horizons and underlying shale. This often results in reduced forage production, especially on the steeper slopes.

Mapping Unit 028-033 - This soil association comprises about 15 percent of the study area. The general slope gradients are from 6 to 15 percent, but many slopes to 20 percent are common as mapped here. Baked rock and shale outcrops are numerous.

Typically, soil 8028 has a platy, brown, clay loam A horizon and a dark brown, clay loam B2t horizon. Below this is fractured baked rock. Depth to the baked rock is about 6 inches. This soil is a member of the loamy, mixed, mesic, family of Ustollic Haplargids.

Typically, soil 8033 has a friable, granular, channery loam A horizon and a very friable, granular, reddish brown, channery loam C horizon. Below this is fractured baked rock with many voids between the fragments. Depth to the baked rock is about 1 foot.

The surface infiltration rate is high and little precipitation is lost as runoff except on the very steep slopes. However, these soils have a limited capacity for moisture retention and all excess moisture percolates through the fractured baked rock. This moisture is not available for plant use. These soils are droughty and productivity is low.

Mapping Unit 029-036 - This soil association represents about 1 percent of the study area. It combines a soil and a nonsoil feature. This mapping unit is mapped near the upper slopes of baked rock, sandstone, and shale outcrops. Baked rock outcrops are the most common nonsoil features. Soil 8029, as mapped in this association, is very similar to its description in mapping unit 035-029.

Precipitation enters the soil at a moderate rate and moves through the soil slowly. During periods of torrential rain, much of the precipitation is lost as runoff. The soil mantle is nonsaline and nonsodic, but the underlying shale is usually moderately to highly saline. Productivity in this mapping unit is limited by the bedrock outcrops and the limited amount of moisture available for plant use.

Mapping Unit 029-031 - This soil association represents about 24 percent of the study area. Soil 8029 is very similar to its description in mapping unit 035-029.

Typically, soil 8031 has a granular, light brownish gray, clay A horizon, and a fine-textured (clayey) transitional C horizon that grades to weathered shale at a shallow depth of 0.5 to 1.5 feet. This soil is a member of the clayey, mesic (calcareous) family of Typic Ustorthents.

This mapping unit comprises semibadlands which include narrow ridges and steep complex slopes. The range productivity in this mapping unit is limited by available moisture. Surface gradients are from 15 to 60 percent. Slopes are complex.

Mapping Unit 029-032 - This soil association comprises about 18 percent of the study area. Soil 8029 is very similar to its description in mapping unit 035-029.

Typically, soil 8032 has a friable, granular, calcareous, light brownish gray loam A horizon, and medium to fine textured C horizons which are light olive brown grading to light yellowish brown with depth. Below this is silty shale at about 2.0 to 4.0 feet. This soil is a member of the fine-loamy, mixed, mesic family of Ustic Torriorthents.

This soil association is most commonly mapped in the rolling uplands. Surface gradients are from 10 to 30 percent and slopes may be simple or complex. Surface runoff is moderate to high and the range productivity in this mapping unit is low.

Mapping Unit 029-034 - This soil association represents about 6 percent of the study area. Soil 8029 is described in mapping unit 035-029 and soil 8034 is described in mapping unit 012-034. As mapped in this association, both are very similar to these descriptions.

This mapping unit occupies tabular divides and relatively smooth uplands. The moisture retained by the soil for plant use is relatively high. The soil mantle and the first foot of the shale are nonsaline and nonsodic. Below this depth the shale is often saline.

Mapping Unit 06 - This mapping unit is not a soil series. It consists of steep to near vertical slope breaks between local alluvium and the bottom of narrow bottomed natural drains. It represents less than 1 percent of the study area.

Mapping Unit 033-029 - This soil association comprises about 11 percent of the study area. Soil 8033 is described in mapping unit 028-033 and soil 8029 is described in mapping unit 035-029. As mapped in this unit, both are very similar to these descriptions. The surface relief is characterized by steep slopes and baked rock, shale, and sandstone outcrops. Steep slopes and shallow soils are unfavorable for infiltration and retention of moisture. Productivity of range plants is limited by the limited moisture reserve.

## Moisture Relations in Soils

Moisture regimens in the soils, which function as reservoirs for water used by native vegetation, are a product of the semiarid climate characteristic of the White Tail Butte Study Area. Approximately one-fourth of the moisture arrives as snow during the period when vegetation is dormant (USDA, 1941). Snow is subject to redistribution by winds; hence, the quantity that falls on a site is not necessarily available for infiltration and storage when the snow melts. Moisture stored in the soils as a result of snowmelt is supplemented by water derived from spring and early summer rains. Peak storage is probably achieved at those times. Maximum runoff from the surface probably occurs under conditions where an intense rainstorm occurs coincident with periods of maximum storage in soils.

Void space and quantities of surface available to store water are the two factors that control moisture relations in soils. These two factors are, therefore, the basis for the concepts, analyses, and interpretations presented in this section. A complete discussion of the concepts used has been presented by Miller and McQueen (1978, in press).

Soils associated with plant communities, occupying the various habitats occurring naturally in the area, were sampled in September 1976. All the measurements required to define moisture relations were obtained as products of the method of McQueen and Miller (1968) for measuring the force with which moisture is retained. The retention force is determined from the moisture content of standard filter papers at equilibrium with moisture in samples augered from consecutive depth increments in soil profiles. All the soil obtained from each auger increment is retained so its volume weight (VW) can be determined. Amounts of void space available for infiltration and storage of water are computed from VW values for each depth increment. Void-moisture capacity (VMC) values, in percent of dry weight, are computed, assuming that soil particles have a density of 2.65 $g/cm^3$ and that the density of water is 1 $g/cm^3$. The equation used is:

$$VMC = 100\left(\frac{1}{VW} - \frac{1}{2.65}\right)$$

This relationship is presented graphically in Figure 2. The influence of differences in amounts of adsorptive surface in soils on quantities of water that can be retained, over the moisture range from saturation to ovendry, were determined using the modeling technique proposed by McQueen and Miller (1974). The soil, for which a graphic model is presented in Figure 3, has one-half adsorptive surface per unit of weight as compared to the filter paper standard. As a result, quantities of water adsorbed as multimolecular films to external surfaces of soil particles are consistently one-half the quantities adsorbed to surfaces of fibers in the paper.

A similar graphic model of moisture content-retention force relationships can be created for any sample of soil if moisture content and retention-force

data are acquired under conditions where only adsorbed water is present. The line representing quantities of water adsorbed is extended down from $10^{6.25}$ g/cm$^2$ on the vertical axis through a point representing the moisture content of the soil and the retention force determined from the filter paper at equilibrium with the soil. Soils that contain expanding latice clays, unlike the filter paper, can adsorb water within their structure. There is evidence (Miller and McQueen, 1972) that this occurs under conditions where retention forces exceed $10^5$ g/cm$^2$.

Water adsorbed as multimolecular films tends to drain down from the adsorption-moisture capacity (AMC) level where 16 molecular layers are adsorbed and the retention force is $10^0$ or 1 g/cm$^2$. Drainage continues to the moisture-retention capability (MRC) level where 10 molecular layers remain adsorbed and the retention force is 222 or $10^{2.346}$ g/cm$^2$. The retention force increases from 1 to 2.46 and gradually to 6.05, 36.6, and finally to 222 g/cm$^2$ as drainage slows proportionately. The final large increase results in drainage becoming insignificant at the MRC level where the retention force is $10^{2.346}$ or 222 g/cm$^2$. During this process, the retention force increases 2.46 times as each molecular layer of water is desorbed. The logarithm of 2.46 is 0.391; therefore, the exponent of the retention force increases by 0.391 as each molecular layer is desorbed.

Molecular dimensions of void spaces in a given depth increment of soil can be used to approximate infiltration rates. The average size of void available for infiltration and storage of water can be approximated in terms of molecular dimensions of water. This is done by dividing VMC values by MRC values and multiplying by 10, because 10 molecular layers are adsorbed at the MRC level. Infiltration data at sites where a large rainfall-simulating infiltrometer (Lusby and Toy, 1976) was used were made available by Lusby (unpublished data, 1976) for comparison with void-dimension data. The data plot has a linear relationship (Fig. 4) that permits estimation of rates of infiltration within confidence limits of plus or minus 9 mm/hr. Since void size and adsorptive surface are controlling factors, the relationship is applicable anywhere.

## Study Sites

A variety of sites ranging from steep uplands to valley floors were characterized in the White Tail Butte Study Area. Locations of individual sites are marked on the topographic map presented in Figure 5. The land tends to slope to the north and south off an east-west trending upland, along which the road traversing the area is located. As a result, the sites tend to have either a northerly or southerly orientation. Slopes of north-facing sites are generally steeper than south-facing slopes (see Fig. 6). This is in agreement with observations made by Hadley (1961) in a study of effects of microclimate on slope morphology and drainage basin development.

Data for defining moisture relations in soils is included for each study site in Table 22, Appendix D.

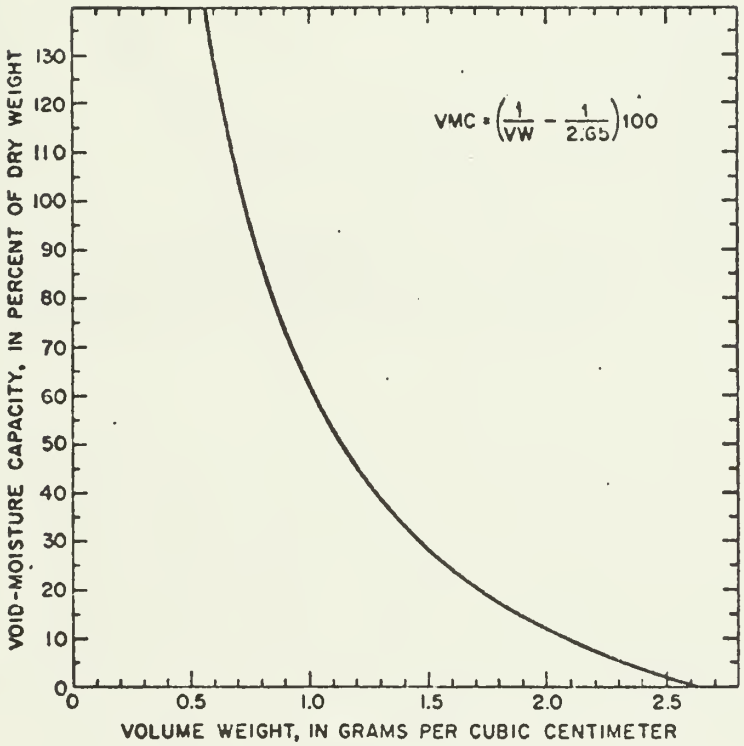



Figure 2 -Relationship used to determine void-moisture capacity (VMC) of soils from volume weight (VW).

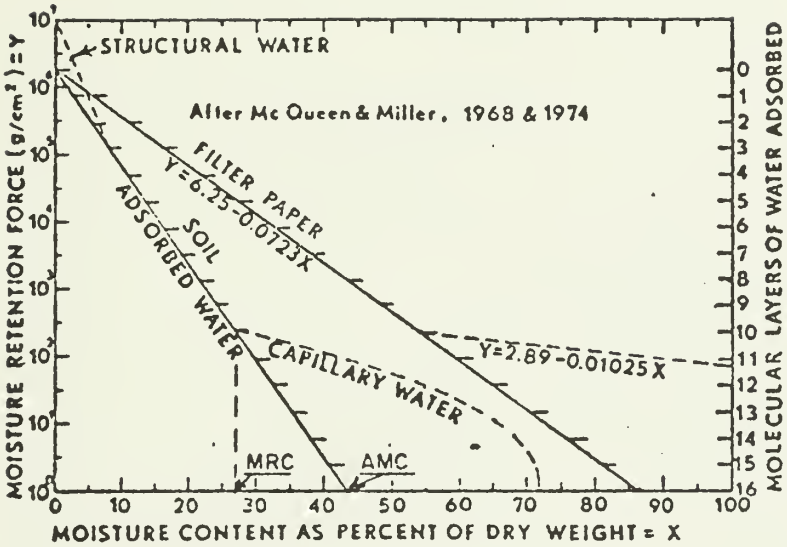



Figure 3 —Calibration relationships (McQueen and Miller, 1968) for determining moisture-retention force from moisture content of standard filter papers at equilibrium with moisture in samples of soil, and graph illustrating similar relations in a soil with one-half the adsorptive surface.

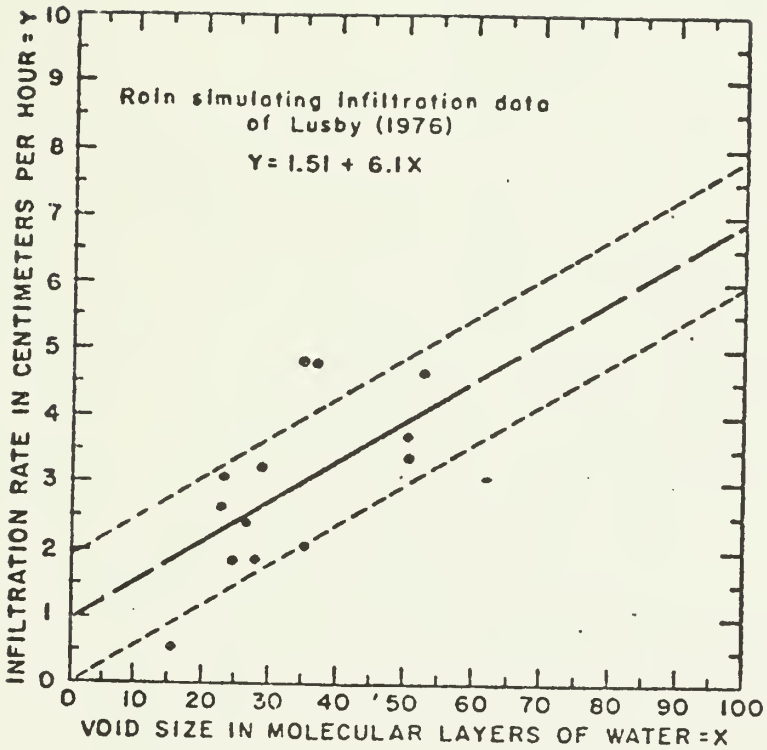
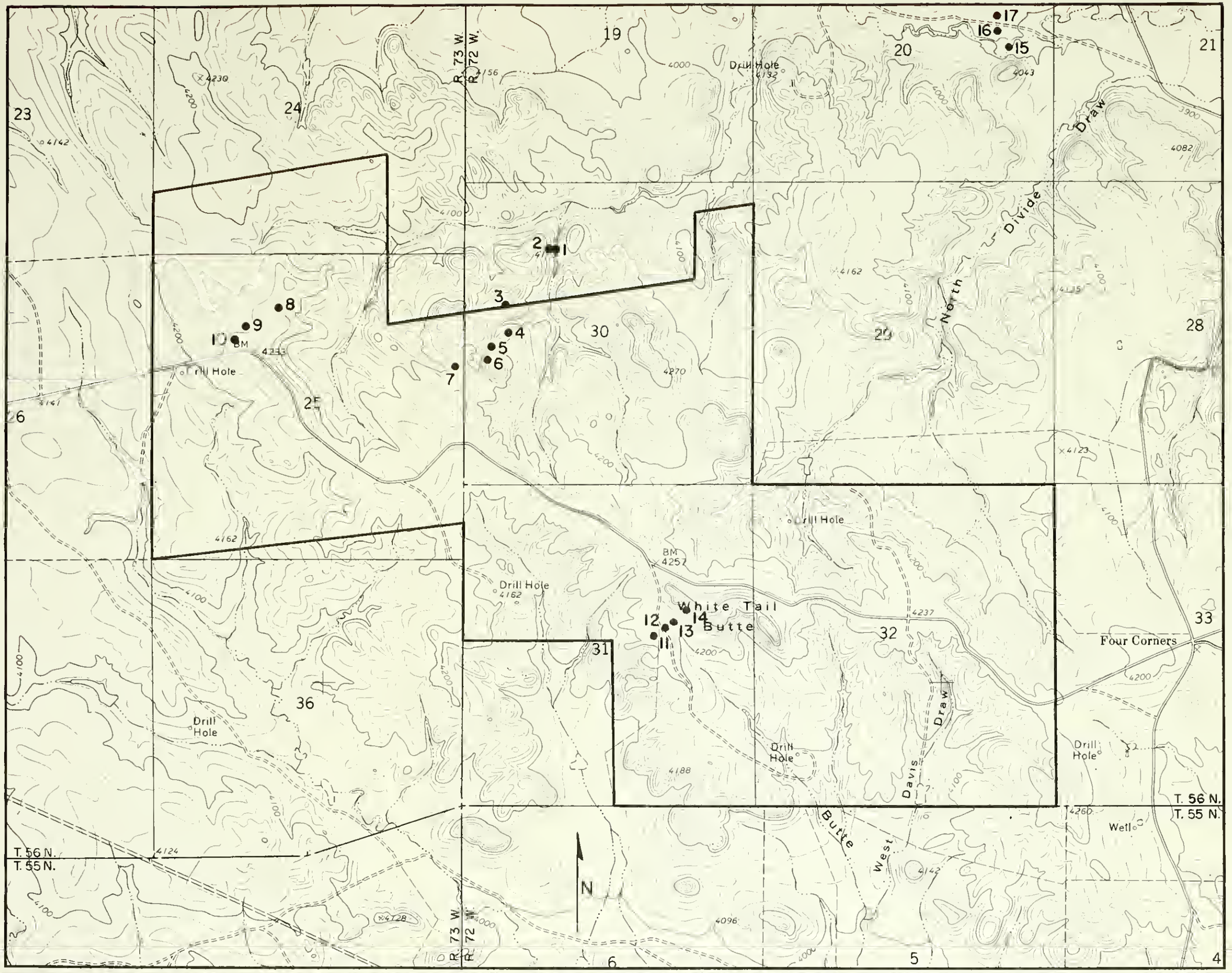



Figure 4 -Relationships between size of voids and rate at which water infiltrates into soils. Dashed line represents confidence limits based on the standard error of estimate obtained for the data.

Figure 5




Base from U.S. Geological Survey
White Tail Butte
7½-minute quadrangle

Figure 5.--Locations of sampling sites for defining moisture relations in soils of the White Tail Butte area, Wyoming--1976.

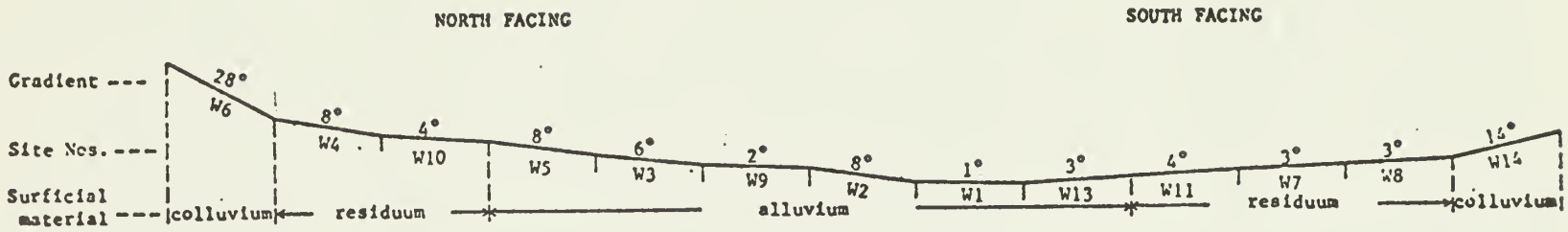



Figure 6 -Schematic diagram showing the influence of orientation on slope gradients, and relationship of types of surficial materials to topographic positions.

Figure 6

Quantities of water that can be present in soils between the limits provided by void-moisture capacity (VMC) and minimum levels of storage (MS) are divided into adsorbed and drainable portions as shown in Figures 7 through 12. Adsorbed moisture capacity (AMC) is computed as the difference between moisture-retention capability (MRC) and MS values. Drainable moisture is computed as the difference between VMC and MRC values. Both are computed to the depth where drainable moisture is capable of occurring. Moisture contents initially computed as percent of the dry weight of soil are converted to numbers indicating depths of adsorbed or drainable water. This is done by multiplying percent moisture by the average VW of the depth increment involved. The product of this multiplication is then multiplied by the depth of the soil increment. The result is the amount of water expressed as a depth of water in millimeters. These are the values shown within the graphs of Figures 7 through 12.

## Colluvial Soils

Steep uplands with slopes in excess of $10^{o}$ are covered by a mantle of soil consisting of coarser particles left behind as finer particles were eroded away. As a result, soils with the least moisture-retention capability (MRC) and the highest void-moisture capacities (VMC) occur on these areas as illustrated in Figure 7. This mantle of material is underlain by weathered bedrock that has higher moisture-retention capabilities and progressively smaller void-moisture capacities.

The large void-moisture capacities relative to small moisture-retention capabilities results in voids capable of allowing 50 and 30 molecular layers of water to flow between soil particles in the upper 0.1 m of soil for sites 6 and 14, respectively. Initial rates of infiltration, therefore, were 3.9 and 2.7 cm/hr for the two sites as computed from the relationship in Figure 7. Runoff will occur if rainfall exceeeds these rates of permeability. As soils are wetted to greater depths, decreases in void size result in decreased permeability. As a result, runoff could result from prolonged rains of lower intensities.

Moisture normally derived from snow is sufficient to recharge the soil from minimum storage (MS) to retention capability levels. Approximately 150 mm of water can be derived from snow that normally falls during the period from October through April, which is a quantity of water similar to the 144 mm depleted between moisture-retention capability and minimum storage at site W14.

The presence of voids in excess of retention-capability levels to considerable depth indicates that the water derived from May and June rains is adsorbed as films in excess of retention-capability levels. The force that plants must exert to obtain water diminishes by 2.46 times for each additional layer of water adsorbed. This factor is probably the reason why midgrasses predominate on sites 6 and 14 (Table 23).

Table 23 - Plant cover, in percent, at sites on steep uplands

| Site | W6 | W14 |
|---|---|---|
| Total live vegetation | 79 | 61 |
| Midgrasses | 59 | 40 |
| Short grasses | 0 | 17 |
| Shrubs | 20 | 2 |
| Forbs | 0 | 2 |

The influence of orientation on moisture availability to plants is also discernible from the data. The south-facing site W14 has less cover and short grasses present with midgrasses. A comparison of maximum levels of retention force achieved per unit of water depleted is possible only in the upper 0.5 m of soil. An average force of 35 $g/cm^2$ is required per millimeter of water on the north-facing slope as compared to 74 $g/cm^2$ on the south-facing slope. This higher index of energy requirement per unit of water is responsible for the smaller amount of cover and the presence of species that can survive in drier habitats.

Site 6 is also representative of large areas with a mantle of red clinker or baked rock fragments. It is impossible to auger to the base of the solum in soils containing rock fragments of this nature. Areas where clinker occurs can be defined from the reddish tinge on aerial photographs of the study area taken with color film. Clinker areas with a cover of grass can be assumed to have shallower mantles of soil over bedrock than clinker areas with a cover of sagebrush. Soils containing fragments of rock normally have more void space than soils without rock. As a result, these materials are less readily compacted and are more permeable. These soils, therefore, could be used advantageously after mining on the steeper slopes where runoff and erosion might otherwise be problems.

## Residual Soils

Residual soils occur on gently sloping (3 to $8^{o}$) uplands (Fig. 5) with a mantle of soil that has been derived from weathering of the underlying bedrock (see Figs. 8 and 9). Void-moisture capacities at the surface are relatively large. The weathered bedrock beneath has higher moisture-retention capabilities than the colluvial material that forms a mantle on steeper areas. As a result, the average void size is smaller at depth than at the surface. This results in low levels of permeability when the surface 0.1 m of soil is initially wetted (2.2 to 3.1 cm/hr). Void-moisture capacities and void size diminish with greater depth, so rates of permeability diminish proportionately. Void-moisture capacities

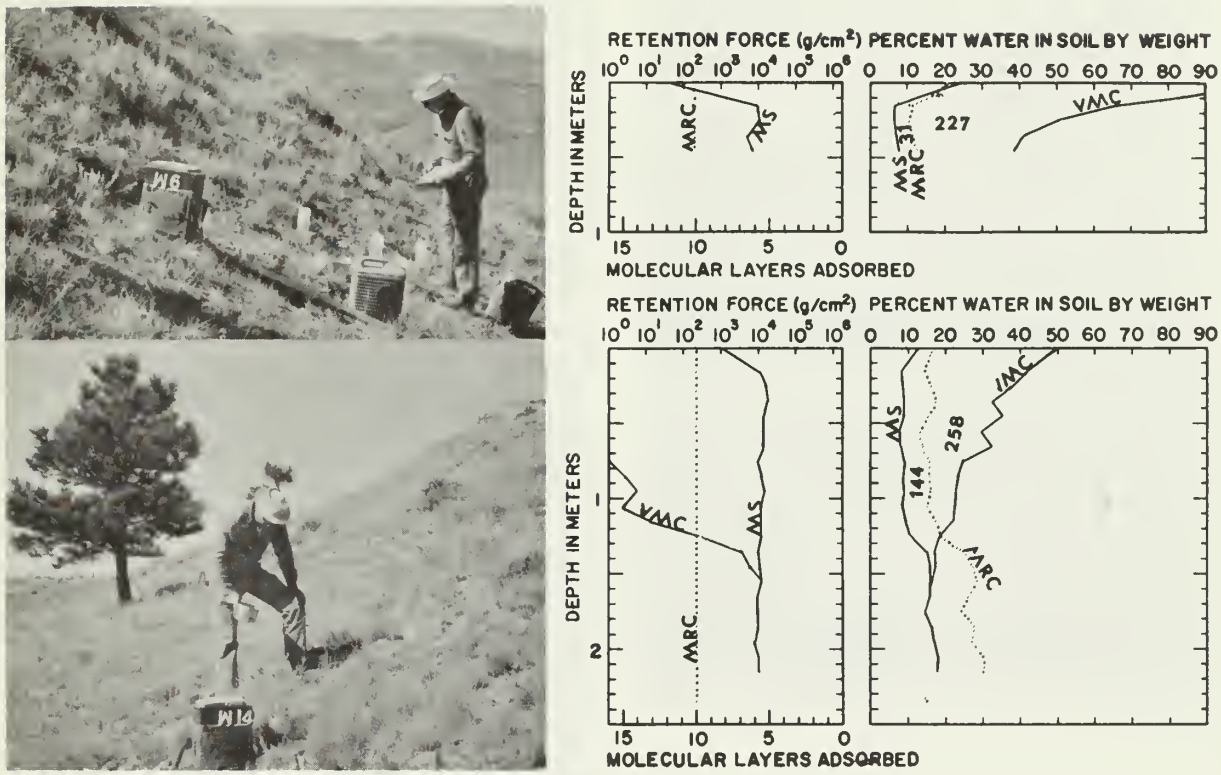



Figure 7 --Photographic aspect and moisture-retention characteristics of steep upland sites with colluvial soils.

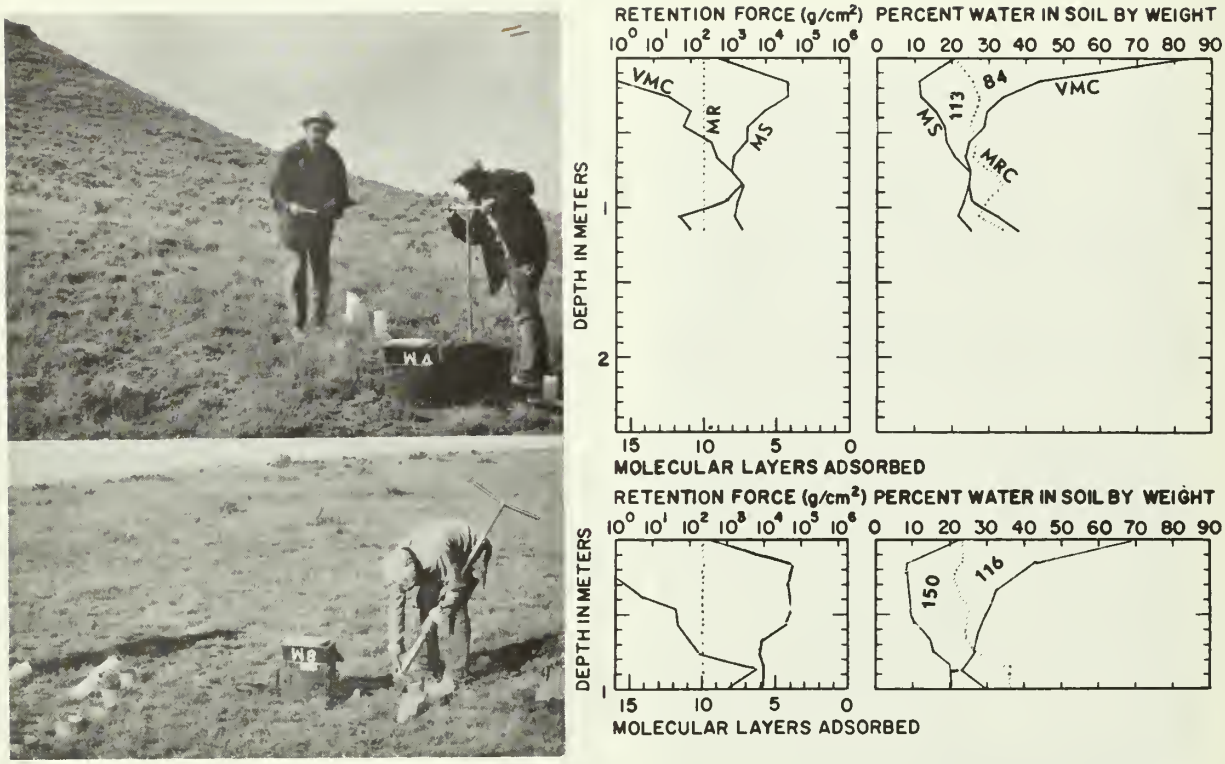



Figure 8 --Photographic aspect and moisture-retention characteristics of sites with shallow residual soils.

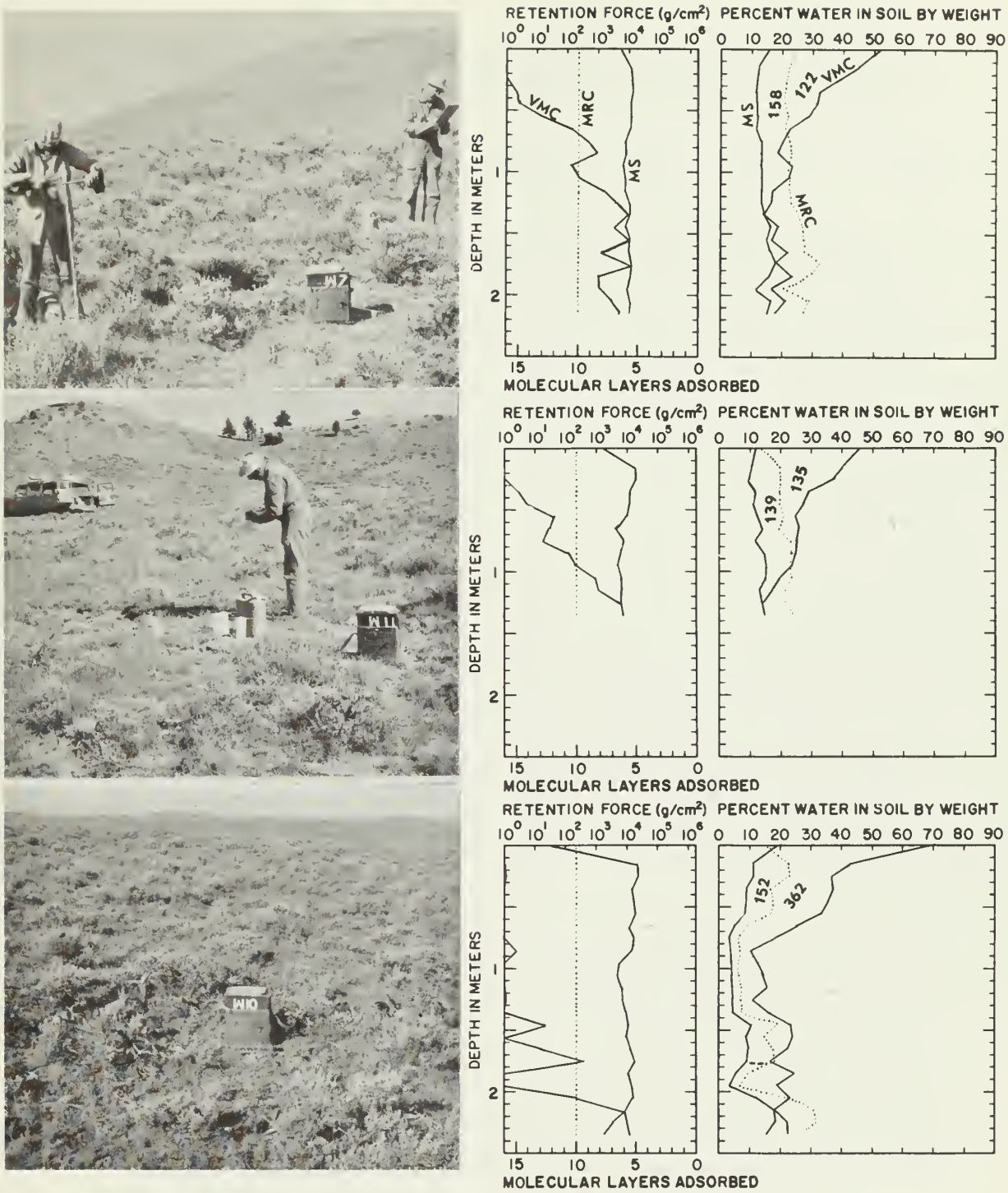



Figure 9 -Photographic aspect and moisture-retention characteristics of sites with deep residual soils.

diminish below retention-capability levels at the contact with bedrock and continue to diminish with depth in the weathered rock. At the base of the profile void-moisture capacities are equal to minimum storage.

Sites W4 and W8 (Fig. 8) have the shallowest soils, but the most permeable surfaces, and are covered primarily by grasses (Table 24).

Table 24 - Plant cover, in percent, at sites on residual soils

| Site | W4 | W8 | W7 | W11 | W10 |
|---|---|---|---|---|---|
| Total live vegetation | 60 | 76 | 62 | 50 | 59 |
| Midgrasses | 49 | 26 | 10 | 25 | 10 |
| Short grasses | 11 | 50 | 12 | 10 | 20 |
| Shrubs | 0 | 0 | 40 | 15 | 24 |
| Forbs | 0 | 0 | 0 | 0 | 5 |

This again, as in the case of sites 6 and 14, is probably the result of water being stored in excess of retention-capability levels because of limitations in void space. Sites (W7, W11, and W10, Fig. 9 ) with deeper soil development have different amounts of big sagebrush occurring with grasses (Table 24). The larger void-moisture capacities of these soils probably results in water being stored as thinner films than in the sites (W4 and W8) with less void space. The presence of big sagebrush is probably the result of higher levels of force that must be exerted per unit of water desorbed.

Quantities of water normally falling as snow are approximately equal to average amounts of water desorbed, between moisture-retention capability and minimum storage levels, for the five residual soils sampled. Amounts of tightly adsorbed water depleted from storage vary from 113 to 158 mm, but the average for the five sites is 142 mm. This probably indicates that snow blows off some of the sites and accumulates on others. Apparently, most of the snow that melts enters these soils. Additional water falling as rain during May and June could be stored as films in excess of retention-capability levels. Storm intensities that exceed the permeability of the soil, which may be saturated above some impeding zone, could cause runoff under these conditions.

## Upland Alluvial Soils

Soils, which are probably members of the Fort Collins series, are present in uplands where big sagebrush occurs with an understory of grasses (Fig. 10), while grasses are predominant in soils that would probably be considered members of the Bidman series (Fig. 11).

Void-moisture capacities do not become equal to minimum storage at the base of the solum in these soils, so film flow or vapor movement to greater depths is possible.

Sites with the most grass present as compared to sagebrush (Fig. 10) have the highest void-moisture capacities and, therefore, the highest initial levels of permeability. Rates of permeability progressively decrease as voids in excess of moisture-retention capability are wetted, so runoff will occur sooner from soils with the least drainable void space. Site W9 has the least drainable void space (55 mm) of the three sites shown in Figure 10. Water stored in drainable voids would be capable of migrating to greater depths as film flow, which is slower than gravity drainage.

Big sagebrush would tend to trap snow that falls on or blows into these areas. Infiltration from snowmelt would be slow, so water derived from this source could migrate to appreciable depths as film flow. This would also be true for water in excess of snowmelt derived from rain that might be temporarily perched above depths where void-moisture capacities become equal to or smaller than moisture-retention capability.

Water stored as films less than 10 molecular layers thick, as indicated by dashed lines in Figure 10, would require more force to utilize it than water stored as thicker films. The proportion of sagebrush (Table 25) is greatest on the site (W9) with the least void space for storage of water.

Table 25 - Plant cover, in percent, on shrub-dominated alluvial upland sites

| Site | W5 | W3 | W9 |
|---|---|---|---|
| Total live vegetation | 75 | 74 | 73 |
| Midgrasses | 33 | 29 | 7 |
| Short grasses | 8 | 8 | 4 |
| Shrubs | 34 | 33 | 62 |
| Forbs | 0 | 4 | 0 |

Alluvial soils where grasses dominate occur on the lower portions of foot slopes or in small swales that drain areas where sagebrush is dominant (Fig. 11). Grass-covered areas are not as capable of holding blowing snow as readily as shrub-covered areas. Runoff from snow melting farther upslope could be a source of extra moisture to sustain grasses that occur on these areas. At site W2, which is a foot slope, void-moisture capacities are less than at sites W1 and W13, which are situated in drainageways (Table 26). Higher void-moisture capacities beneath drainageways are

Figure 10

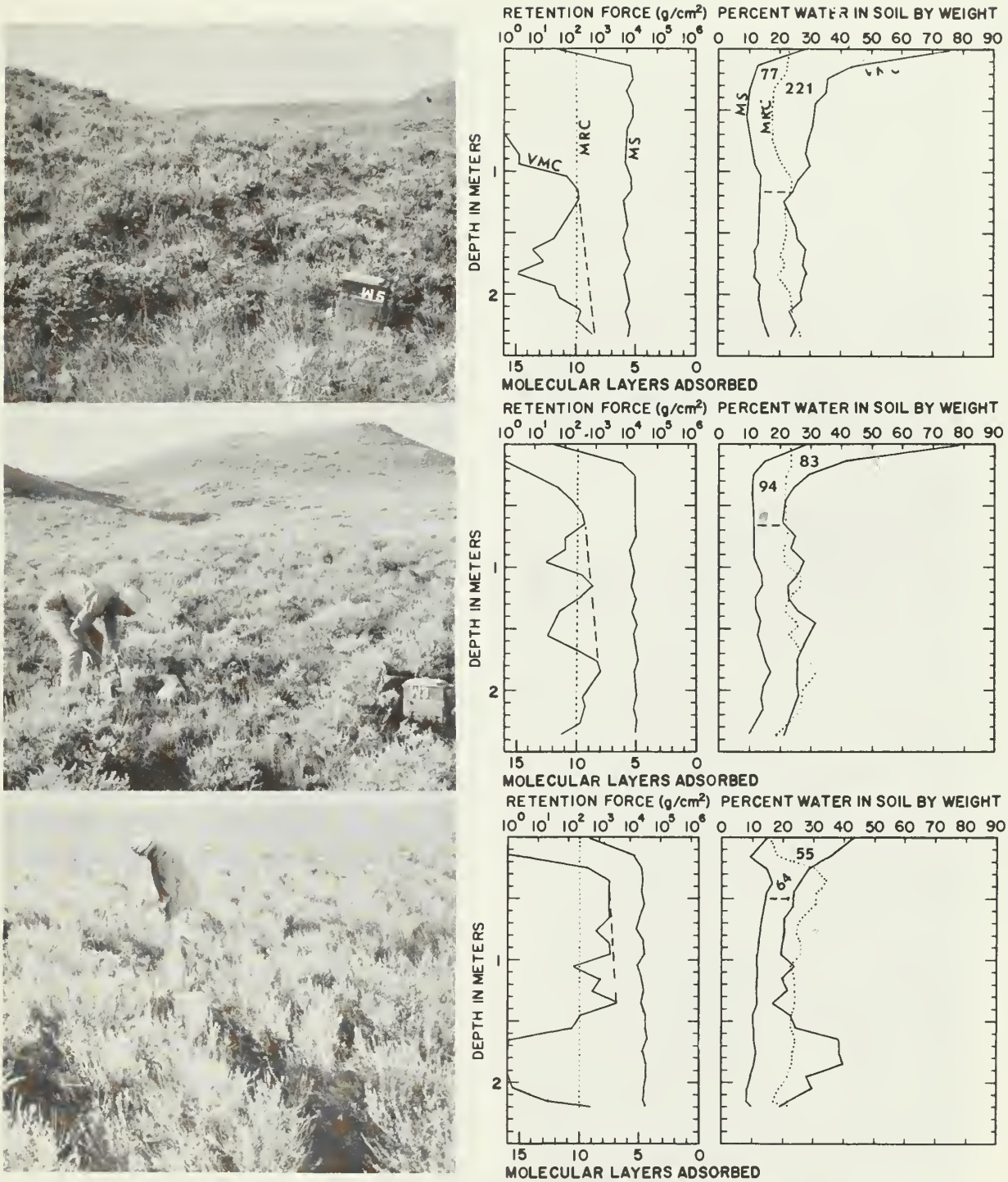



Figure 10 -Photographic aspect and moisture-retention characteristics of shrub-dominated alluvial upland sites.

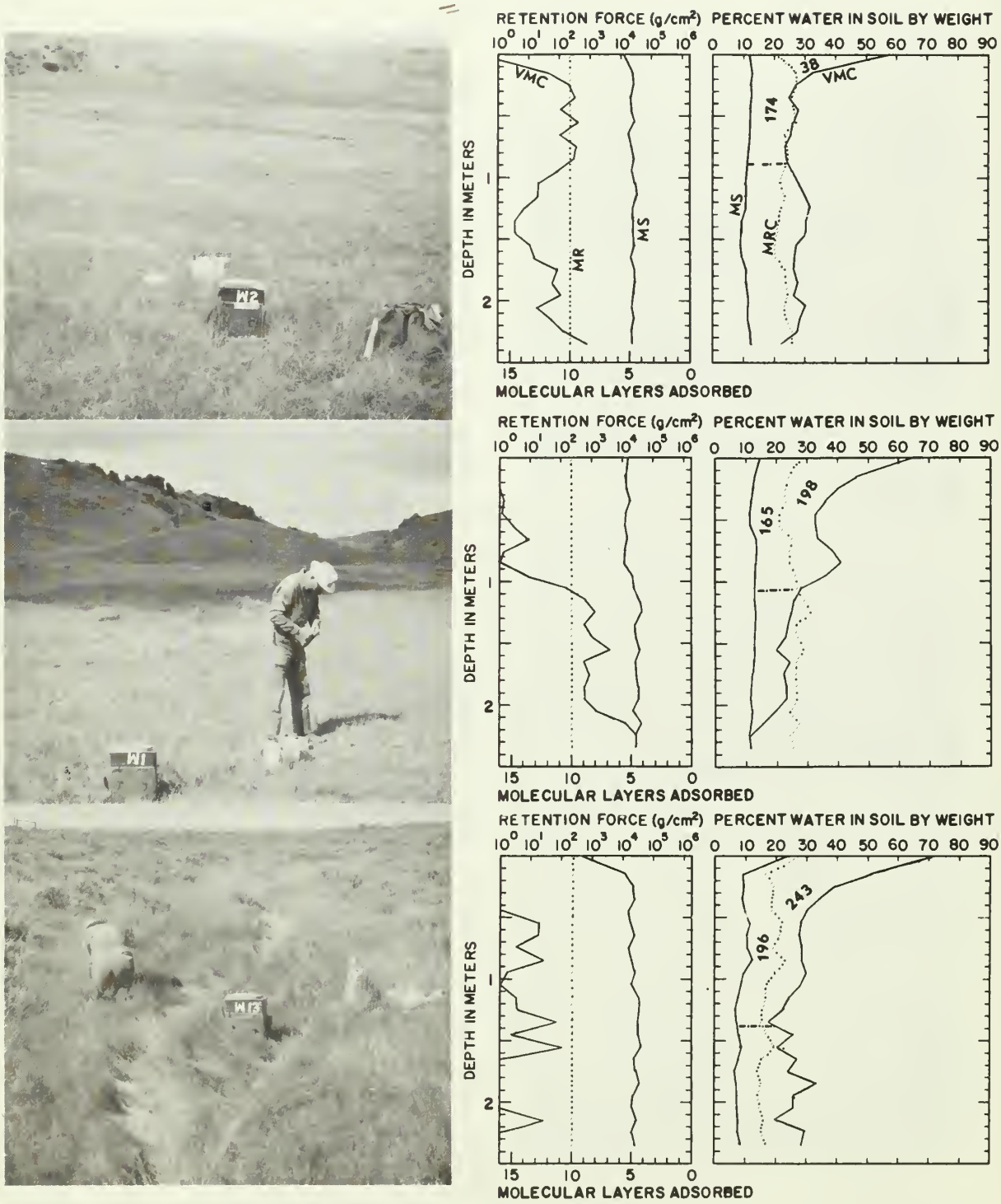



Figure 11 --Photographic aspect and moisture-retention characteristics of alluvial soils in low areas.

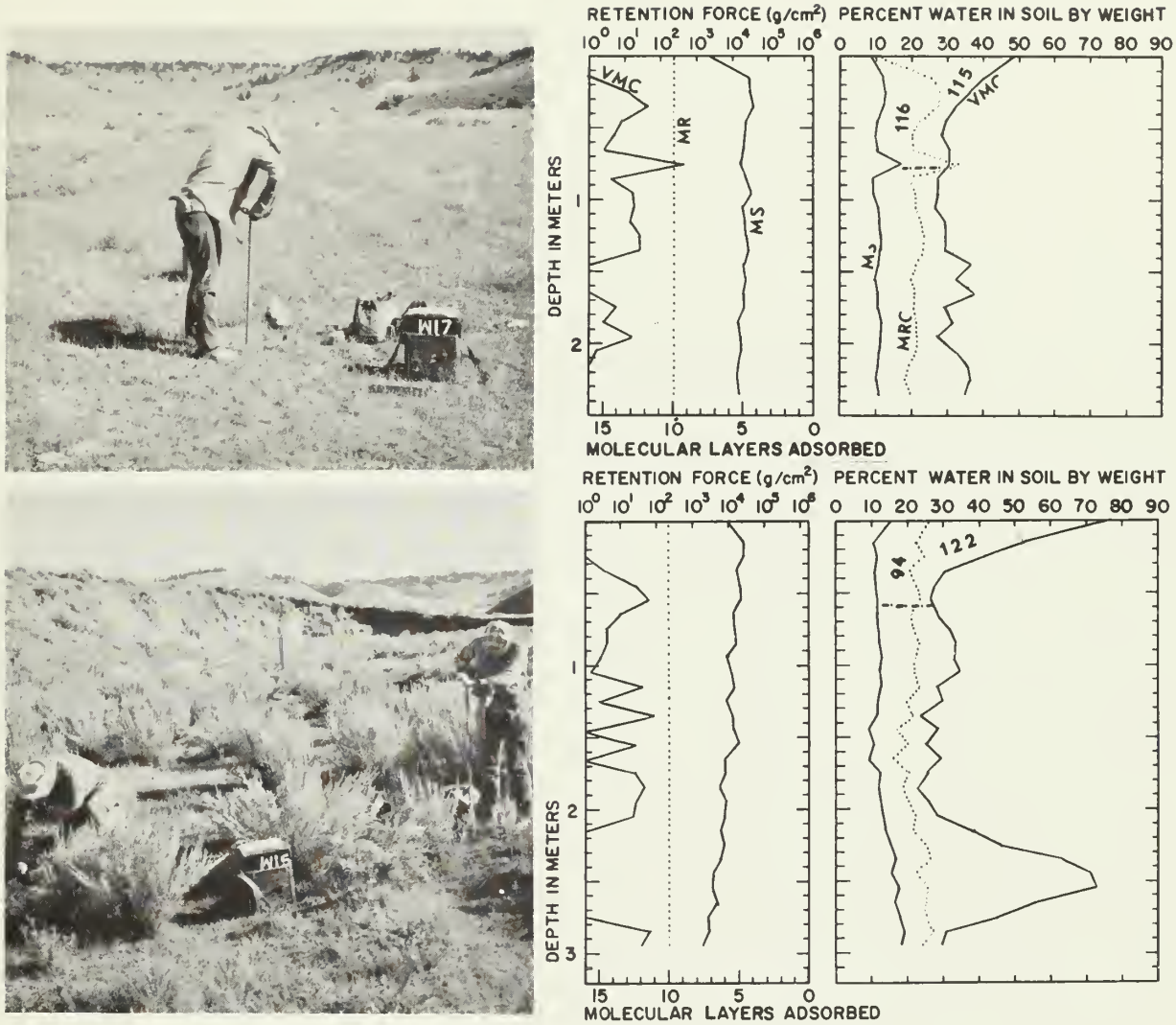



Figure 12 --Photographic aspect and moisture-retention characteristics of sites on valley-floor alluvium.

Table 26 - Plant cover, in percent, on grass dominated, upland alluvial sites

| Site | W2 | W1 | W13 |
|---|---|---|---|
| Total live vegetation | 63 | 85 | 100 |
| Midgrasses | 37 | 45 | 99 |
| Short grasses | 21 | 40 | 0 |
| Shrubs | 2 | 0 | 1 |
| Forbs | 3 | 0 | 0 |

are probably the result of wetting in response to a positive head as water flows over the surface of the soil.

Here, again, unsaturated void space, less than the moisture-retention capability, can be wetted by water initially perched in large voids near the surface. Grass probably dominates these sites because large quantities of water are available. This is corroborated by the fact that most cover occurs on site W13 which has the most drainable void capacity (243 mm, Fig. 11).

Table 27 - Plant cover, in percent, on valley alluvium sites

| Site | W17 | W15 |
|---|---|---|
| Total live vegetation | 51 | 93 |
| Midgrasses | 35 | 54 |
| Short grasses | 15 | 0 |
| Shrubs | 0 | 39 |
| Forbs | 1 | 0 |

## Valley Alluvium

It was necessary to go outside the study area to sample soils representative of valley floor conditions (Fig. 12). These sites have void-moisture capacities that permit water, initially stored near the surface in excess of moisture-retention capability levels, to flow down into soil that is drier than retention-capability levels. The predominance of grasses over the areas indicate that extra moisture is derived either from snow blown in from uplands or from run-in water.

Two levels of alluvial terraces were sampled; big sagebrush occurred with grasses on the upper terrace while silver sagebrush was present with grasses on the lower terrace (Table 27). Soil at the base of the lower site (W15) becomes increasingly moist with depth (Fig. 11). This is the result of capillary rise from ground water, and possibly moisture exuding into drier soil from the roots of silver sagebrush.

The channel is incised deep enough that flooding of the first level (W15) does not occur every year, and flooding of the upper level (W17) would be very infrequent. Soil moisture is, therefore, derived primarily from snowfall, blown-in snow, rain, and runoff from side slopes.

## GREENHOUSE [1/]

### Introduction

In the past, surface mining for coal has generally resulted in soil materials being buried beneath a mixture of spoils. Spoils exposed at the surface often originated from bedrock strata directly overlying the coal seam, resulting in a poor quality plant medium. In many cases, this has led to a severe problem in revegetation of surface-mined lands.

The Surface Mining Control and Reclamation Act of 1977 (P.L. 95-87) was enacted in an effort to enhance proper reclamation and revegetation of surface-mined lands. In selecting the most suitable overburden (soil and bedrock) materials for use in revegetation, this Federal law stipulates that . . . "All topsoil shall be removed in a separate layer from the areas to be disturbed, unless use of substitute or supplementary materials is approved by the regulatory authority . . . if use of substitute or supplementary materials is approved, all materials to be redistributed shall be removed" (30 CFR 816.22(b)). Note: In the White Tail Butte Study Area, the State of Wyoming, Department of Environmental Quality Land Quality Division is the present Regulatory Authority.

The objective of this greenhouse study was to evaluate the suitability of overburden (soil and bedrock) materials in the White Tail Butte Study Area for use as plant growth media.

### Methods

The initial task in the greenhouse study was to determine the field capacity of the overburden samples. The equipment used to determine field capacity included: plastic tubes 1-3/4 inches in diameter, plastic cups, and plastic sheets. Four hundred grams of each overburden sample were weighed and placed in the plastic cylinders which had been sealed at the bottom by a plastic sheet, and packed by tapping the side of the cylinder. Twenty milliliters of water were then added (5 percent of the overburden by weight) and the top was sealed with a plastic sheet. After 24 hours, the bottom plastic sheet was removed and the dry overburden fell into the plastic cup, leaving the moist overburden in the cylinder. The dry overburden was weighed and the field capacity (FC) calculated by the following equation:

$$FC = \frac{20 \text{ g } H_2O}{400 \text{ g - Weight of dry overburden}} \times 100$$

The field capacity percentage was the basis for the amount of water each pot received daily.

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1/ This study was conducted by the Department of Agronomy, Colorado State University, Fort Collins, Colorado, for the Water and Power Resources Service, U.S. Department of the Interior, under Contract No. 6-07-DR-50310.

## Fertilizer Treatments

Two thousand grams of each overburden and soil sample were weighed into each of two pots. Each pot was fertilized with 100 ppm of nitrogen as reagent grade $Ca(NO_3)_2$ and 80 ppm phosphorus as reagent grade $Ca(H_2PO_4)_2H_2O$. The reagents were added in solution as 10 and 50 ml aliquots respectively, then mixed into the soils and overburden. Where sufficient soil material was not available for a 2 kg sample weight, the aliquot sizes were adjusted to maintain a fertility level of 100 ppm N and 80 ppm P.

## Seeding and Growth

Western wheatgrass (Agropyron Smithii var. Arriba) was the test species. This species was chosen because it is one of the most abundant native grasses in the Western United States and will probably be used in many revegetation programs.

At the time of seeding, approximately 250 g of overburden were removed from each pot. Then water was added to each pot to bring them to field capacity. Forty seeds were placed in each pot and the previously removed dry overburden placed on the seeds. All pots were then covered with paper to retard evaporation and to allow the water to move to the surface by capillary rise. The pots were checked daily, and upon germination, each pot was uncovered and the date recorded. The date when ten plants had emerged was recorded, as was the severity of salt crusting. After germination, all pots were weighed daily and deionized water was added to bring the soil to field capacity. Maximum water use was approximately 25 percent of field capacity per day.

When the majority of the plants, in all pots, reached a height of 10 cm, the number of plants in each pot was recorded and each pot was thinned to 16 plants.

Two highly productive loam soils were included in this experiment as overall standards ($A_1$ horizon Platner series and $A_1$ horizon Kimm series). Greenhouse data on the standard soils is included at the end of Table 28, Appendix E.

Western wheatgrass was grown for 59 days on the overburden samples from the White Tail Butte Study Area, Wyoming (September 16 to November 14, 1976).

## Harvesting

The plants were clipped at a height of 2 cm above the soil surface to minimize contamination by soil splashed on the plants during watering. The harvested plants were then washed in 0.05 normal HCl and rinsed in distilled water so tissue analysis could be done on the plant samples. The plants were dried in a forced air oven at 70° for 24 hours and then weighed to the nearest 0.01 gram.

Observations taken at the time of harvest included (1) the presence of shoot growth from rhizomes; (2) the degree of soil surface cracking; (3) the amount of salt crusting; and (4) the average plant height.

In comparing average plant height and plant dry weight it can be seen that there is no direct correlation. These differences are believed to be partially due to variation in light response in different seasons. Also, within experiments, a portion of the variation appears to be related to the amount of shoot growth originating from rhizomes, in that overburden samples with a low yield and tall average plant height generally had very little or no growth from rhizomes, while those samples with a high plant yield and a lower average plant height generally had a relatively large amount of growth from rhizomes. Also, the samples with a higher content of clay generally had the largest amount of growth from rhizomes.

## Results

Large differences in Western wheatgrass growth are evident on various overburden samples (Photograph 7). Because there was a variation in plant dry weights for the standard soils used in this greenhouse experiment, relative yields will be used in this discussion. Actual and relative yields are presented in Table 28, Appendix E. Relative yield was calculated as a percentage of the yield of the Platner standard soil. For purposes of this discussion, relative yields less than 33 percent will be considered low, 33-67 percent medium, and above 67 percent high.

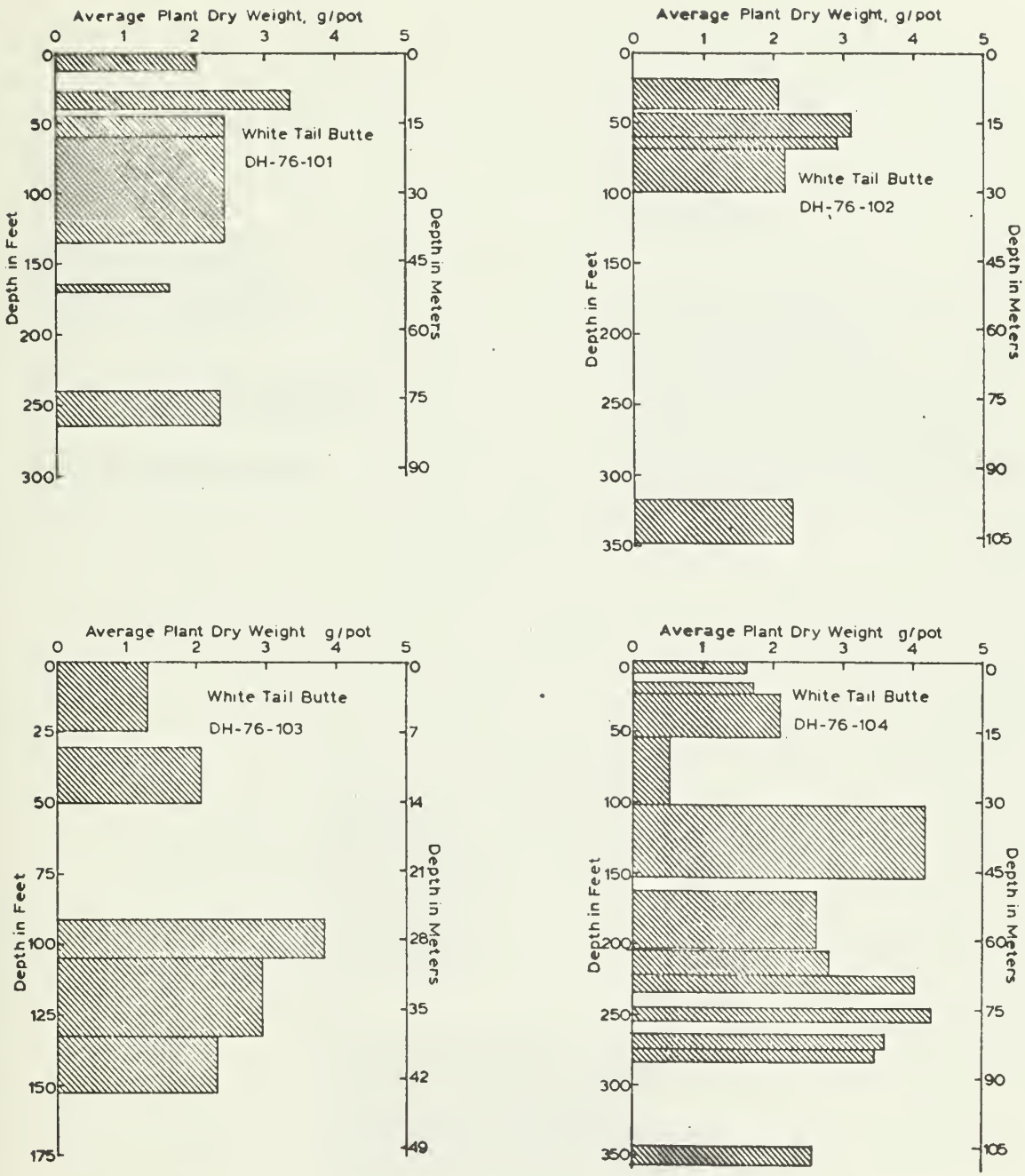
Bedrock core samples from the White Tail Butte Study Area produced medium to high yields. Relative yields for 10 percent of the samples were low, 46 percent were medium, and 44 percent were high (Figures 13 and 14).

It must be recognized that the yields produced on these bedrock samples were obtained under controlled laboratory conditions. It is highly questionable whether these bedrock materials would produce similar yields under actual field conditions. Many of the bedrock materials may be unsuitable for use as revegetative media due to their low fertility, fine (clayey) or coarse (sandy) texture, slow permeability, erodibility, and/or salinity/sodicity problems.

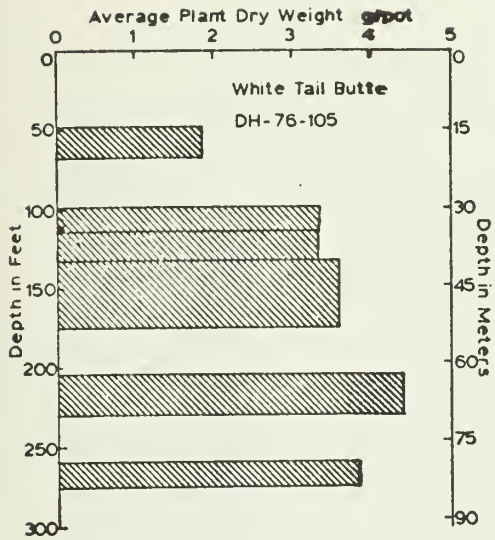
Soil profile samples from the study area generally yielded less than the bedrock samples. However, the soil samples rated better for use as plant growth media due to more favorable physical and chemical properties. Relative yields for 12 percent of the soil samples were low, 66 percent were medium, and 22 percent were high (Figure 15). The samples which produced low yields were usually saline.

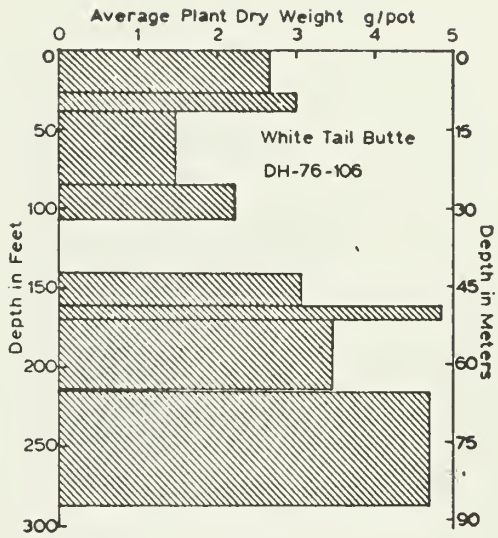
## Discussion

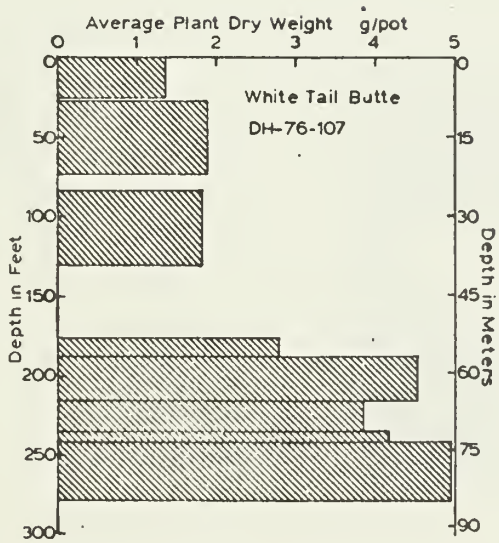
Large differences in yield were noted among bedrock and soil samples. Overburden samples which had relative yields less than 33 percent would



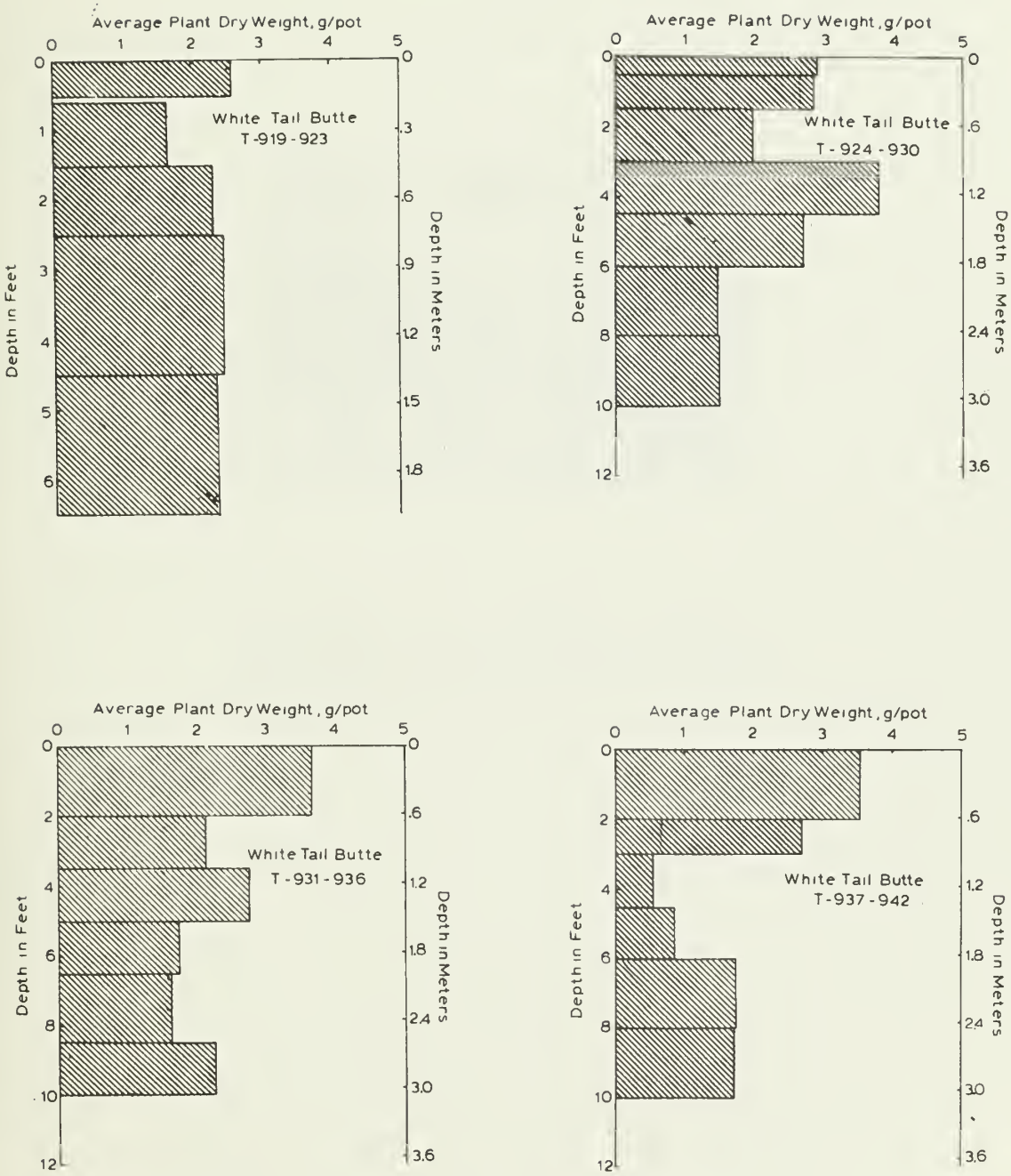

Yields of western wheatgrass on overburden samples from coreholes DH-76-101, DH-76-102, DH-76-103, and DH-76-104, White Tail Butte site in Wyoming.




Yields of western wheatgrass on overburden samples from coreholes DH-76-105, DH-76-106, and DH-76-107, White Tail Butte site in Wyoming.




Yields of western wheatgrass on soil profile samples from the White Tail Butte site in Wyoming.

Photograph 7 — — — Range in Western wheatgrass growth on overburden samples from the White Tail Butte Study Area.

definitely not be suitable as plant growth media. The samples with relative yields larger than 33 percent include some strata which would make a favorable plant growth media under field conditions.

In the greenhouse study, overburden samples with the higher field capacities generally yielded the most. In the field, under arid and semiarid conditions, these fine-textured materials would be the more droughty soils because of low infiltration rates causing surface runoff and evaporation. Thus, growth differences reported in this greenhouse study will give only an indication of the overburden suitability as a plant growth media. When extrapolating greenhouse results to field conditions, the physical and chemical characteristics of the overburden must be analyzed along with the greenhouse yield data to make interpretations on the suitability of the strata as a plant growth media.

## Greenhouse Yields and Observations

The degree of surface cracking of the overburden was given a numerical designation as follows:

0 - none
1 - very slight
2 - slight
3 - moderate
4 - extreme

The degree of salt crusting was also observed and recorded as follows:

0 - no salt crust present
1 - 1-30% of surface area covered with salt crust
2 - 31-60% of surface area covered with salt crust
3 - 61-90% of surface area covered with salt crust
4 - 91-100% of surface area covered with salt crust

Blackened leaf tips were observed and frequency of occurrence, within pots, was recorded as follows:

0 - no plants with black leaf tips
1 - 1-4 plants with black leaf tips
2 - 5-8 plants with black leaf tips
3 - 9-12 plants with black leaf tips
4 - 13-16 plants with black leaf tips

These blackened leaf tips (5-10 mm) changed to a brown color after 1-2 weeks. Although the leaf tips died back, there was no evidence of overall yield reduction of plants so affected.

Roman numerals I and II in Table 28, Appendix E, refer to replication. Duplicate pots were run on all soil and overburden samples for which there was adequate soil material.

## Additional Data

Blackening of the leaf tips was observed on various samples. This blackening of the leaf tips was hypothesized to be boron toxicity, but work done by Water and Power Resources Service personnel in Billings, Montana, showed that there was no correlation between the amount of hot water soluble boron and the amount of blackened leaf tips. This blackening of leaf tips was also noted in previous greenhouse studies on overburden from the Alton, Hanna Basin, Otter Creek, and Taylor Creek EMRIA sites.

In some cases, sufficient soil material was not available for a sample weight of 2.0 kg. It was not known whether significant yield decreases per pot would result if the sample weight was less than 2.0 kg, so an experiment was conducted using three soils with five sample weights (2.0, 1.9, 1.8, 1.6, and 1.4 kg). The soils used were the Platner and Kimm standard soils and the $C_{ca}$ horizon from the Kimm series which will be called Kimm $C_{ca}$ in this report. All treatments were replicated three times, making a total of 45 pots. Western wheatgrass was grown on the soils for 56 days following seeding (January 17 to March 13, 1976). The samples were fertilized and seeded and the plants thinned and harvested following the previously mentioned procedures. An analysis of variance (AOV) was run on the data (Table 29) to determine if there were any significant differences in yields. The results showed that there were significant differences in yields between the sample weight (0.001 level). Since the AOV showed there were significant differences, a Duncans Multiple Range test was conducted. These results showed that there were significant differences in yield at the 5 percent level between all sample weights except 2.0 versus 1.9 kg; 1.9 versus 1.6 kg; and 1.6 versus 1.4 kg. This shows that for statistical comparison purposes, a sample weight of 1.9 or 2.0 kg is needed for this study.

Yields of western wheatgrass as a function of weight of soil per pot.

| Soil Sample | Pot Wt. (Kg.) | Plant Dry Weight I | II | III |
|---|---|---|---|---|
| Platner | 2.0 | 2.89 | 2.79 | 2.35 |
| Platner | 1.9 | 2.34 | 2.65 | 2.65 |
| Platner | 1.8 | 2.47 | 2.61 | 2.56 |
| Platner | 1.6 | 2.16 | 2.56 | 2.00 |
| Platner | 1.4 | 2.67 | 2.32 | 2.40 |
| Kimm $A_1$ | 2.0 | 4.85 | 4.56 | 4.39 |
| Kimm $A_1$ | 1.9 | 4.29 | 4.34 | 4.33 |
| Kimm $A_1$ | 1.8 | 3.65 | 4.52 | 4.16 |
| Kimm $A_1$ | 1.6 | 4.46 | 3.55 | 3.73 |
| Kimm $A_1$ | 1.4 | 3.64 | 3.31 | 3.51 |
| Kimm $C_{ca}$ | 2.0 | 2.83 | 2.86 | 2.56 |
| Kimm $C_{ca}$ | 1.9 | 2.97 | 3.00 | 3.22 |
| Kimm $C_{ca}$ | 1.8 | 2.42 | 2.29 | 2.35 |
| Kimm $C_{ca}$ | 1.6 | 2.19 | 2.87 | 2.98 |
| Kimm $C_{ca}$ | 1.4 | 2.24 | 2.38 | 2.15 |

| Pot Weight (Kg) | Mean Plant Dry Weight (g) |
|---|---|
| 2.0 a* | 3.34 |
| 1.9 a | 3.31 |
| 1.8 b | 3.00 |
| 1.6 b, c | 2.94 |
| 1.4 c | 2.74 |

* Any two pot weights followed by the same letter are not significantly different at the 0.05 level.

## VEGETATION

Areal cover and soil surface conditions were measured by the first-contact point-quadrat method. A frame containing 10 pins was placed at three-step intervals requiring a transect of about one-tenth mile to obtain 600 pin measurements in each vegetation type. Current growth of vegetation and yields of mulch were measured in three 9.6 $ft^2$ plots in each vegetation type. Plant materials were oven-dried and weighed and are reported as pounds per acre (Table 30). Estimated carrying capacities are based on these yields with adjustments made for such factors as distance from water, slope, and palatability of species. These estimates are for cattle; different evaluations of the data would be required for other classes of livestock and game species. Range condition estimates are based on principles proposed by Dyksterhuis (1949).

Steep topography and a variety of soil parent materials in the area provide habitats for a number of contrasting plant communities. This variation in vegetative cover includes grasslands, shrublands, and one tree type.

The silver sagebrush-green needlegrass type (see Table 30 and Plate 34) is found on floodplains adjacent to intermittent stream channels. This cover is the most productive of the types sampled. Although nearly level terrain and nearness to water have resulted in heavier use of this than other types, range condition has not been greatly lowered. Range condition is good to excellent. Better livestock distribution would cause this type to be even more productive. Estimated carrying capacity for this type is 1.4 acres per animal unit month.

The one nearly pure grassland type is represented by the extensive stands of bluebunch wheatgrass that are commonly found on coarse-textured soils derived from porcellanite ("scoria" or "clinker"). These stands are generally in good to excellent condition and were the second most productive type sampled. High infiltration rates and low runoff cause most of the annual precipitation to enter the soil and become readily available to plants. Other species commonly found in this type include silverleaf psoralea, blue grama, needle-and-thread, threadleaf sedge, and junegrass. Estimated carrying capacity for this type is relatively high, 1.6 acres per animal unit month, but careful management is required to maintain good stands of bluebunch wheatgrass. It is rapidly destroyed by heavy grazing in spring and early summer.

On gently sloping terraces and fans, a frequently encountered type is blue grama-big sagebrush. Ease of access and nearness to water has caused this to be one of the few types in the study area to show appreciable signs of deterioration. Range condition for this type is judged as fair to good. Short grasses (blue grama and buffalograss) have increased, midgrasses (western wheatgrass and green needlegrass) have decreased, and shrubs (big sagebrush and snakeweed) have increased on or have invaded this type. These changes have decreased the potential yield and carrying capacity (about 3.8 acres per animal unit month) of this site.

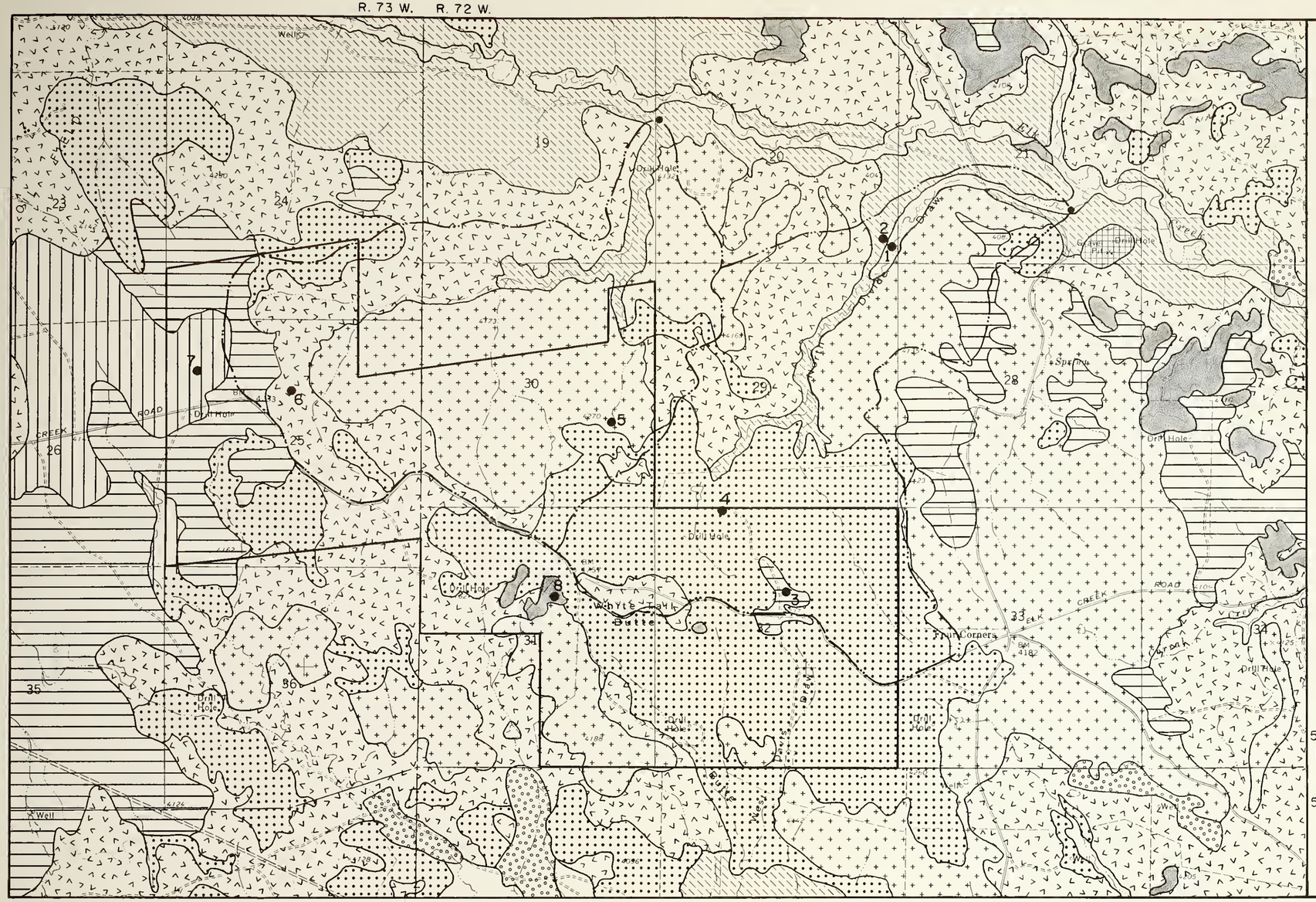
Relatively flat uplands have a predominately grass (western wheatgrass-blue grama) cover with a thin overstory of big sagebrush. Most of these sites are at the top of steep slopes, some distance from water, and probably have never been heavily grazed. Range condition for this type is good to excellent and the carrying capacity of 4.2 acres is probably normal for the site although it would be slightly greater if water were more readily available. A similar type (big sagebrush-western wheatgrass) occurs on a relatively flat area at the west edge of the study area but, partly because of readily available water and possibly soil differences, there is some evidence of range deterioration as is indicated by greater abundance of big sagebrush and yarrow. This type has the lowest estimated carrying capacity, 6.2 acres per animal unit month, of the types sampled.

Much of the study area is characterized by steep slopes. Exposure effects, varieties of geologic materials exposed, and varying depths of colluvial deposits result in a complex of vegetation types on these slopes. These are mapped as two vegetation types: (1) generally on the steepest slopes is a relatively sparse cover mapped as bluebunch wheatgrass-big sagebrush, and (2) on slightly less steep slopes as the big sagebrush-bluebunch wheatgrass type.

The shallow soils of the bluebunch wheatgrass-big sagebrush type have a total live cover of only 46 percent and an estimated carrying capacity of 5.3 acres per animal unit month. Although the cover is sparse, this type is considered to be in fair to good range condition. The site is highly erodible and should always be moderately grazed.

An indication of the diversity of habitats in the big sagebrush-bluebunch wheatgrass is shown by the number of species (24) that occurred in the sample plots. Only in the ponderosa pine-little bluestem type with 26 species was this number exceeded. The big sagebrush-bluebunch wheatgrass type is one of the more productive types sampled and has an estimated carrying capacity of 2.9 acres per animal unit month. Because of the steep slopes and potential erosion hazard, this type should be moderately grazed.

The ponderosa pine-little bluestem type is found in favored locations such as snow blow-in areas and north-facing slopes and on coarse soils. This type usually occurs near ridge tops. Palatable forage species, summer shade, and cover attract livestock and game animals to this site and heavy animal use has caused some deterioration. This is the only type that had an appreciable amount of the invader, cheatgrass brome. Nevertheless, this type is productive (estimated carrying capacity of 1.8 acres per animal unit month) and is considered to be in good range condition.




EXPLANATION

- Silver sagebrush-green needlegrass occurs on flood plains of major stream channels (site 1, table 30).
- Bluebunch wheatgrass forms extensive stands on porcellanite or "clinker" (site 5).
- Blue grama-big sagebrush is found on gently sloping terraces and fans (site 2).
- Western wheatgrass-blue grama occurs on flat tablelands that form some of the drainage divides (site 3).
- Big sagebrush-western wheatgrass occurs on gently sloping lands in the western portion of the study area (site 7).
- Bluebunch wheatgrass-big sagebrush is a type with relatively sparse cover found on steep slopes or "breaks" (site 4).
- Big sagebrush-bluebunch wheatgrass (site 6) is similar to site 4 but is found on moderately steep slopes and has greater plant cover.
- Ponderosa pine-little bluestem occurs near drainage divides on coarse, colluvial, and often rocky soils (site 8).
- Cultivated land.
- ● 3 Vegetation sampling site.
- Study area boundary.

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1000 0 1000 2000 FEET

VEGETATION MAP OF THE WHITE TAIL BUTTE AREA, WYOMING--1976

Base from U.S. Geological Survey
White Tail Butte
7½-minute quadrangle

Table 30 --Percent cover by vegetation, mulch, bare soil, and rock as determined by first-contact point-quadrat method plus weights of vegetation and mulch in pounds per acre

[Weights are in parentheses]

| Vegetation types. . . | | Silver sagebrush-Green needlegrass | | Blue grama-Big sagebrush | | Western wheatgrass-Blue grama | | Bluebunch wheatgrass-Big sagebrush | | Bluebunch wheatgrass | | Big sagebrush-Bluebunch wheatgrass | | Big sagebrush-Western wheatgrass | | Ponderosa pine Little bluestem | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site numbers. . . . . | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | |
| Genus and species | Common name | Cover | Yield | Cover | Yield | Cover | Yield | Cover | Yield | Cover | Yield | Cover | Yield | Cover | Yield | Cover | Yield |
| Trees | | | | | | | | | | | | | | | | | |
| Pinus ponderosa | Ponderosa pine | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 26.6 | ------- |
| Shrubs | | | | | | | | | | | | | | | | | |
| Artemisia cana | Silver sagebrush | 35.3 | (503.0) | 3.9 | (15.3) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (11.3) | ---- | ------- | ---- | ------- |
| Artemisia frigida | Fringed sagebrush | 0.2 | ------- | 1.4 | (13.3) | ---- | (5.0) | ---- | ------- | 0.3 | (10.3) | ---- | ------- | ---- | ------- | ---- | ------- |
| Artemisia tridentata | Big sagebrush | 2.2 | ------- | 12.6 | (154.0) | 8.8 | (77.8) | 7.2 | (22.7) | 2.2 | (28.0) | 10.6 | (78.3) | 29.3 | (166.7) | ---- | (14.0) |
| Chrysothamnus nauseosus | Rubber rabbitbrush | ---- | ------- | ---- | ------- | ---- | ------- | 0.3 | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Eurotia lanata | Winterfat | ---- | ------- | ---- | ------- | ---- | ------- | 0.5 | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Gutierrezia sarothrae | Snakeweed | ---- | (6.3) | 6.1 | ------- | ---- | ------- | 5.6 | (89.7) | ---- | ------- | 1.5 | (6.0) | ---- | ------- | 0.8 | (14.0) |
| Opuntia polycantha | Plains pricklypear | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 0.2 | (2.7) | ---- | ------- | ---- | ------- |
| Rosa arkansana | Rose | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (1.3) | ---- | ------- | ---- | ------- |
| Symphoricarpos alba | Snowberry | 0.2 | (98.3) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Symphoricarpos oreophylus | Mountain snowberry | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 0.3 | ------- |
| Yucca glauca | Soapweed | ---- | ------- | ---- | ------- | ---- | ------- | 2.6 | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Grasses and grasslikes | | | | | | | | | | | | | | | | | |
| Agropyron smithii | Western wheatgrass | 10.8 | (101.3) | 8.8 | (345.0) | 26.8 | (166.7) | 2.9 | (44.3) | 3.4 | ------- | 4.0 | (63.0) | 7.7 | (99.3) | 1.3 | (6.0) |
| Agropyron spicatum | Bluebunch wheatgrass | ---- | ------- | ---- | ------- | ---- | ------- | 10.9 | (161.0) | 42.5 | (865.7) | 9.8 | (225.3) | ---- | ------- | 15.7 | (242.0) |
| Agropyron trachycaulum | Slender wheatgrass | ---- | (124.3) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Andropogon scoparius | Little bluestem | ---- | ------- | ---- | ------- | ---- | ------- | 0.7 | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 2.7 | (225.0) |
| Aristida longiseta | Red threeawn | ---- | ------- | 0.2 | ------- | ---- | ------- | ---- | ------- | 0.5 | ------- | ---- | ------- | ---- | ------- | 2.2 | ------- |
| Bouteloua curtipendula | Sideoats grama | ---- | ------- | ---- | ------- | ---- | ------- | 4.1 | (25.3) | ---- | ------- | 0.8 | (12.7) | ---- | ------- | ---- | ------- |
| Bouteloua gracilis | Blue grama | 0.2 | (2.0) | 23.6 | (139.7) | 20.7 | (205.0) | 0.5 | ------- | 8.5 | (8.7) | 9.4 | (28.7) | 5.7 | (6.0) | 0.8 | ------- |
| Bromus commutatus | Hairy chess | 0.3 | ------- | 1.2 | (35.0) | 1.8 | (2.0) | ---- | ------- | 0.7 | ------- | 0.2 | (10.4) | 0.1 | ------- | 0.1 | ------- |
| Bromus tectorum | Cheatgrass brome | ---- | (5.0) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 10.0 | ------- |
| Buchloe dactyloides | Buffalograss | ---- | ------- | 5.4 | (8.0) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Carex eleocharis | Needleleaf sedge | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 1.0 | (3.7) | ---- | ------- | ---- | ------- | 1.8 | ------- |
| Carex filifolia | Threadleaf sedge | ---- | ------- | ---- | ------- | ---- | ------- | 0.2 | ------- | 2.7 | (17.7) | 2.2 | ------- | ---- | ------- | ---- | ------- |
| Calamovilfa longifolia | Prairie sandreed | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 1.8 | ------- |
| Festuca ovina | Sheep fescue | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 1.3 | ------- |
| Koeleria cristata | Junegrass | ---- | ------- | 0.7 | (10.0) | 1.8 | (27.0) | 0.3 | (9.0) | 1.7 | (8.7) | 4.1 | (24.7) | 2.2 | (36.3) | 0.7 | (3.3) |
| Muhlenbergia cuspidata | Stonyhills muhly | ---- | ------- | ---- | ------- | ---- | ------- | 1.5 | (26.7) | ---- | ------- | 0.7 | (12.7) | ---- | ------- | ---- | (14.0) |
| Poa pratensis | Kentucky bluegrass | 1.2 | (225.3) | ---- | (1.3) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Poa secunda | Sandberg bluegrass | ---- | (5.7) | 0.3 | (10.7) | 1.3 | (13.0) | ---- | ------- | 0.7 | ------- | ---- | ------- | 1.5 | (7.7) | ---- | ------- |
| Schedonnardus paniculatus | Texas crabgrass | 0.5 | (2.7) | 1.9 | (20.3) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Sporobolus cryptandrus | Sand dropseed | ---- | ------- | 1.2 | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Stipa comata | Needle-and-thread | ---- | ------- | ---- | (6.0) | 2.8 | (110.0) | ---- | ------- | 3.2 | (7.7) | 1.2 | (48.3) | ---- | ------- | 2.2 | ------- |
| Stipa viridula | Green needlegrass | 27.5 | (254.3) | 7.5 | (4.0) | 1.8 | (7.8) | 2.6 | ------- | ---- | ------- | 8.0 | (56.0) | 2.5 | (41.3) | 0.7 | ------- |
| Forbs | | | | | | | | | | | | | | | | | |
| Achillea lanulosa | Yarrow | 0.2 | (44.0) | 0.3 | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 0.5 | (0.7) | 2.3 | (97.0) | 0.3 | (1.3) |
| Arenaria sp. | Sandwort | ---- | ------- | ---- | ------- | ---- | ------- | 1.0 | ------- | ---- | (6.7) | 0.5 | (55.3) | 0.3 | ------- | ---- | (8.3) |
| Astragalus sp. | Milkvetch | ---- | ------- | ---- | ------- | ---- | (1.7) | ---- | (30.0) | ---- | ------- | 0.5 | (0.3) | 0.1 | ------- | ---- | ------- |
| Cirsium undulatum | Wavyleaf thistle | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 0.3 | ------- | ---- | ------- | ---- | ------- | ---- | (0.7) |
| Caillardia aristata | Caillardia | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (5.3) |
| Haplopappus spinulosus | Spiny sideranthus | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | 1.0 | ------- | ---- | ------- | ---- | ------- |
| Meriolix serrulata | Primrose | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (9.0) |
| Petalostemum candidus | White prairieclover | ---- | ------- | ---- | ------- | ---- | ------- | 5.1 | (1.0) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Petalostemum purpureum | Purple prairieclover | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (4.7) |
| Phlox hoodii | Hoods phlox | ---- | ------- | 0.2 | (3.3) | ---- | (5.0) | ---- | ------- | 0.5 | (5.3) | 2.4 | (11.0) | 0.5 | ------- | ---- | ------- |
| Phlox longifolia | Longleaf phlox | ---- | ------- | ---- | ------- | ---- | ------- | 0.3 | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Plantago purshii | Wooly Indianwheat | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (0.7) | ---- | ------- |
| Polygonum aviculare | Dooryard knotweed | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (3.0) | ---- | ------- |
| Psoralea argophylla | Silverleaf psoralea | ---- | ------- | 0.3 | ------- | ---- | ------- | ---- | ------- | 3.4 | (60.3) | ---- | (22.7) | ---- | ------- | ---- | ------- |
| Solidago sp. | Goldenrod | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- |
| Sphaeralcea coccinea | Scarlet globemallow | ---- | (5.0) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (0.3) | 0.2 | (1.7) | ---- | ------- | 0.3 | ------- |
| Taraxacum officinale | Dandelion | 1.2 | (2.3) | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (0.3) | 0.5 | (8.0) | 0.1 | (0.3) |
| Tragopogon pratense | Oyster salsify | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (6.0) | ---- | ------- | ---- | ------- | ---- | ------- |
| Vicia americana | American vetch | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (9.3) | ---- | ------- | ---- | ------- |
| | Unidentified forbs | ---- | ------- | ---- | ------- | ---- | ------- | ---- | (36.3) | ---- | (0.7) | ---- | ------- | ---- | (0.3) | ---- | ------- |
| Total live cover (percent) and total vegetation yields (lbs/acre) | | 79.8 | (1.379.5) | 75.6 | (765.9) | 65.8 | (621.0) | 46.3 | (446.0) | 71.6 | (1,029.8) | 57.8 | (682.7) | 52.7 | (466.3) | 69.7 | (547.9) |
| Mulch | | 13.3 | (958.0) | 18.9 | (389.7) | 31.8 | (706.0) | 9.4 | (125.7) | 9.7 | (438.3) | 17.7 | (71.7) | 37.2 | (1,411.7) | 20.6 | (1,715.0) |
| Bare soil | | 7.2 | | 4.8 | | 2.2 | | 39.7 | | 1.0 | | 23.7 | | 10.0 | | 1.2 | |
| Rock | | ---- | | 0.7 | | ---- | | 4.4 | | 17.6 | | 0.8 | | ---- | | 8.3 | |
| Estimated carrying capacity in acres per animal unit month | | | 1.4 | | 3.8 | | 4.2 | | 5.3 | | 1.6 | | 2.9 | | 6.2 | | 1.8 |

# HYDROLOGY

## Purpose and Scope

A study of the hydrology of the Powder River Basin in Wyoming was begun in 1975 to determine the water supply in the basin and to assess the impacts of mining on water resources. A detailed study of the basin was not possible within the scope of the project. However, several small areas were chosen for detailed study in order to test and improve conceptual models that were developed of the hydrologic system from reconnaissance data. The White Tail Butte area was one of the small areas initially selected as a site for detailed ground water study.

Subsequently, the U.S. Bureau of Land Management designated part of the area as an Energy Minerals Rehabilitation Inventory and Analysis (EMRIA) study area. The main purposes of EMRIA studies are to determine the reclamation potential, the problems that would be involved in reclaiming the area, and the measures required to establish satisfactory conditions. EMRIA studies include both ground and surface water; therefore, the work by the U.S. Geological Survey at White Tail Butte was expanded to include surface water, and the water-resources part of the EMRIA study was incorporated into this report.

## Location

The White Tail Butte area is in the Powder River Basin, Wyoming, about 8 miles south of the Montana State line. The total area is about 288 $mi^2$ and was selected to include locations of test wells drilled for the U.S. Geological Survey model-mine study at Recluse, Wyoming, the EMRIA study, and enough adjoining area to include water wells in aquifers that are used in Campbell County, Wyoming.

## Site-Numbering System

Sites in Table 31, Appendix E, and in the text are numbered according to the Federal system of land subdivision in Wyoming. The first number indicates the township, the second the range, and the third the section in which the well is located. Letters following the section number indicate the position of the well in the section. The first letter denotes the quarter section, the second letter the quarter-quarter section, and the third letter, if given, the quarter-quarter-quarter section (10-acre tract). The subdivisions of a section are lettered A, B, C, and D in a counter-clockwise direction, starting in the northeast quarter. The first well in a tract is numbered one (1). Additional wells in the tract are numbered consecutively (see Figure 16).

## Geologic Setting

The general geologic structure and stratigraphy of the Powder River Basin, Wyoming, are shown in Figures 17 and 18. Only the formations exposed in the area and those from which water has been developed in the area are described in this report. The following descriptions, except for the alluvium, are adapted principally from descriptions by Robinson and others (1964).

## Fox Hills Sandstone

The Fox Hills Sandstone of Cretaceous age is the youngest marine formation in the basin. Robinson and others (1964, p. 95-96) describe the Fox Hills on the northern and western flanks of the Black Hills as a sequence of sandstone and shales 125 to 200 feet thick. The Fox Hills is poorly exposed east of White Tail Butte but is described from exposures elsewhere as consisting of two members. The lower member is 50 to 100 feet thick and consists of fine-grained sandstone interbedded with shale and siltstone. Shale is abundant near the base; the Fox Hills grades downward through an interval 10 to 50 feet thick into the Pierre Shale of Cretaceous age. The upper member is fine to medium grained, massive sandstone from 50 to 100 feet thick. The upper member, in places, pinches out or grades laterally into sandstone and shale similar to that in the lower member. Geophysical logs in the White Tail Butte area indicate the presence of the twofold division in part of the area and that the thickness of the formation is about 100 feet.

## Lance Formation

The Lance Formation of Cretaceous age consists of a continental sequence of alternative sandstone, sandy shale, claystone, and carbonaceous shale. The sandstone is fine to medium grained and friable, and the thickness of individual beds ranges from less than 1 inch to more than 25 feet (Robinson and others, 1964, p. 98). Geophysical logs indicate the Lance is about 1,200 feet thick in the White Tail Butte area.

## Fort Union Formation

The Fort Union Formation of Paleocene age is divided into three members: the Tullock, Lebo Shale, and Tongue River. The Tullock, the lowermost member, crops out east of the Little Powder River in a series of dissected ridges. The Tullock consists of fine-grained sandstone; gray, sandy or silty shale; and numerous beds of carbonaceous shale and coal. Most of the sandstone is soft and friable (Robinson and others, 1964, p. 99). The thickness of the Tullock in the White Tail Butte area is about 600 feet. The middle member, the Lebo Shale, crops out along the valley of the Little Powder River and consists mostly of light to dark gray claystone, subordinate lenses of fine-grained sandstone, and carbonaceous shale (Robinson and others, 1964, p. 99-100). The shale is 200-250 feet thick.

The Tongue River is the upper member of the Fort Union and is exposed in the White Tail Butte Area along the bluffs west of the Little Powder River and in much of the uplands. It consists of interbedded fine-grained sandstone, siltstone, sandy shale, carbonaceous shale, and coal. The coal in this member is of current interest for mining in the area. The principal coals, in order of increasing depth, are the Anderson, Dietz, Canyon, Cook, Wall, Pawnee, and Cache. Robinson and others (1964, p. 100) state that the Tongue River Member is about 800 feet thick where exposed along the bluffs west of the Little Powder River.

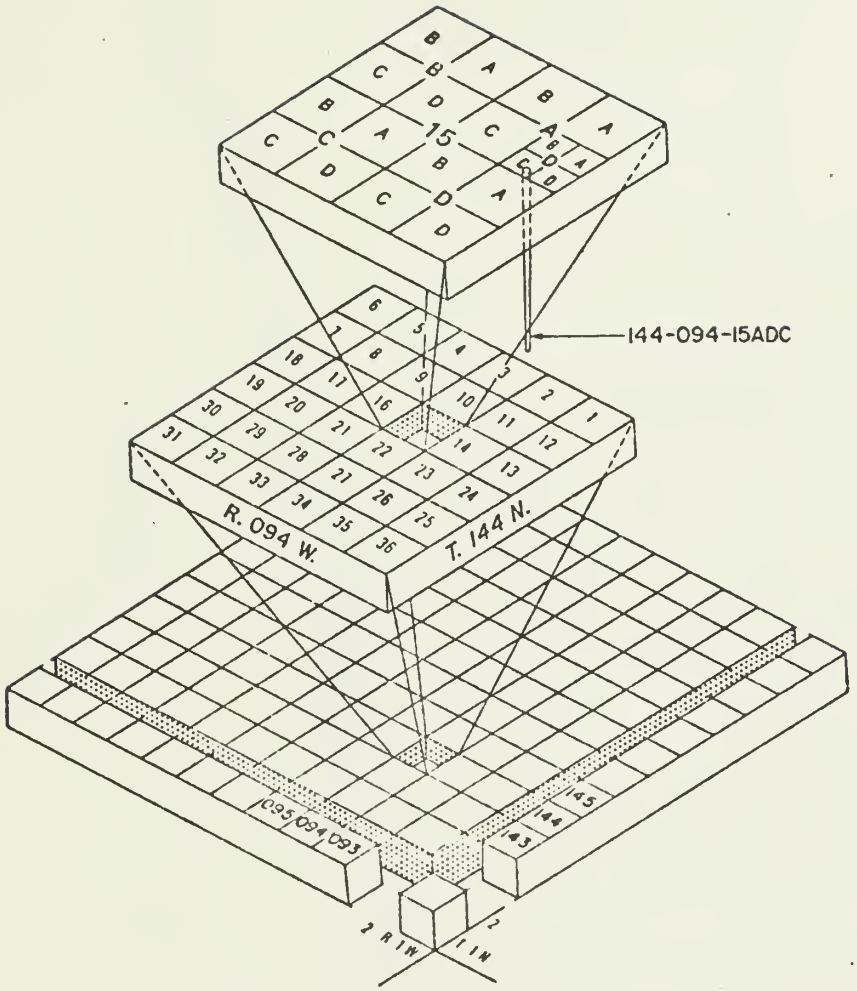



FIGURE 16 --System of numbering wells and test holes.

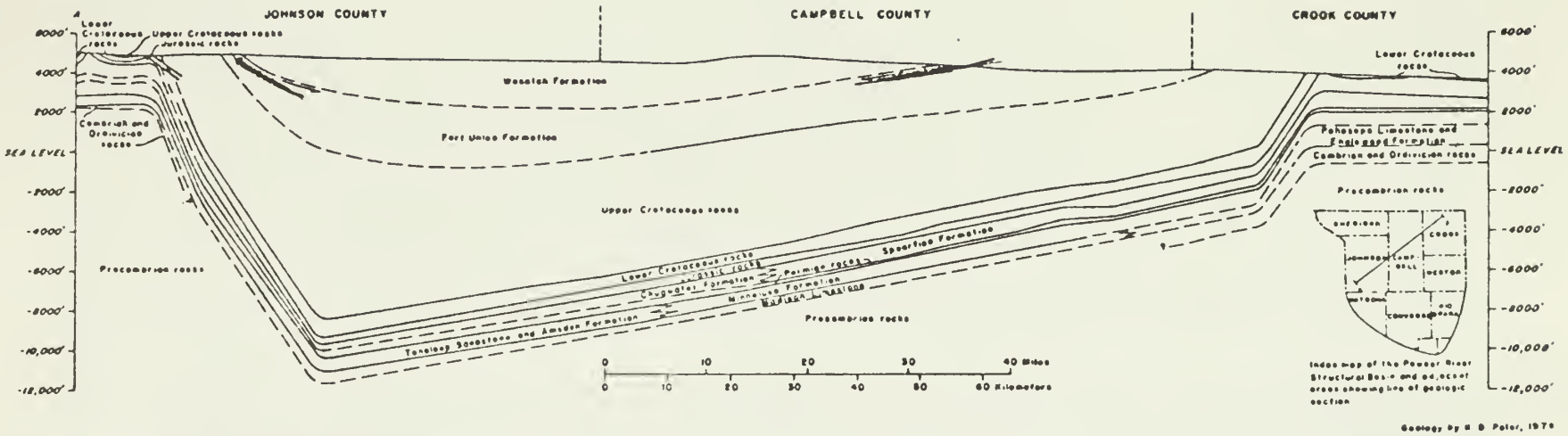



Figure 17 -Generalized geologic section of the Powder River structural basin, northeastern Wyoming.

Figure 17

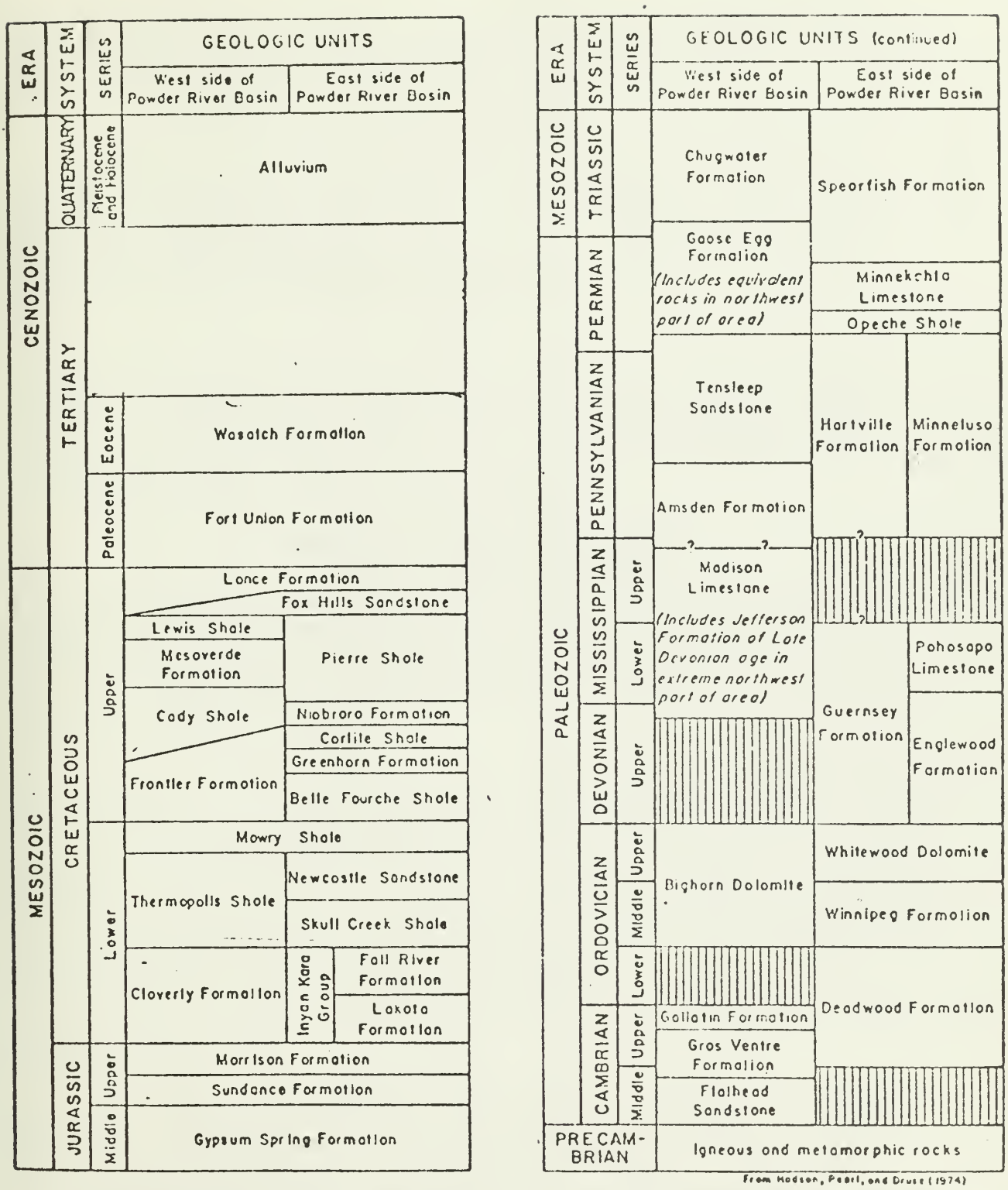



Figure 18 Stratigraphic relation of geologic units shown in Figure 17.

The Tongue River Member thickens toward the center of the Powder River Basin. It is 1,200 to 1,300 feet thick in the Spotted Horse Coalfield on the west side of the White Tail Butte area (Olive, 1957, p. 10).

### Wasatch Formation

The Wasatch Formation of Eocene age caps the divides in the central part of the White Tail Butte area and thickens westward toward the center of the Powder River Basin (Figure 17). The lithology of the Wasatch is similar to the Fort Union. The maximum local thickness in the Spotted Horse Coalfield is more than 700 feet (Olive, 1957, p. 14).

### Alluvium

Alluvium of Pleistocene and Holocene age occurs in the small drainages of the area. The material is locally derived and the gravel-sized particles consist of sandstone and clinkers. Test holes on Elk Creek penetrated a maximum of 30 feet of alluvium along Elk Creek (56N 071W 30DBB02), and the thickness is probably not much greater elsewhere.

## Hydrologic Classification of Land Types Using Rainfall Simulation

Three predominant land types that comprise most of the surface were identified within the White Tail Butte Study Area. These were designated hydrologic classes A, B, and C, and simulation runs were made on each class in August 1976 to determine their hydrologic characteristics. These baseline data will be the basis for comparison with future changes which might result from surface mining.

The extent of each land type was determined from aerial photographs and is shown on Plate 35. Locations where simulation runs were made were designated 1, 2, 3, and 4, and are also shown on Plate 35. Responses similar to those obtained from the applied rainfall could be expected from areas of the same hydrologic class as shown on Plate 35. The simulation sites were chosen to be representative of the soil, vegetation, and relief within each hydrologic class. Data obtained at the sites are shown in Table 32 and photographs of the sites are shown in Figure 19. The number following the site designation incidates whether the soil was dry (1) or wet (2).

Methods used to obtain the data from each simulation site listed in Table 32 are as follows:

1. Runoff--Measured in a Parshall flume with 1-inch throat. Readings of stage made at 1-minute intervals and converted to discharge in cubic feet per second. From these data, a runoff hydrograph was constructed and total volume of runoff was computed and expressed in inches per unit area. From these data, an infiltration rate curve was also constructed by subtracting the runoff from the rainfall applied for each 1-minute interval and expressed as the infiltration rate in inches per hour.

2. Precipitation--Measured in a network of rain gages within the study area. Rainfall for the total area was computed using the Thiessen Polygon method.

3. Sediment yield--Water samples were obtained from the outflow at 3-minute intervals and were analyzed for sediment concentration. The sediment concentrations were plotted and a concentration curve was drawn between points. From this curve, a concentration was obtained for each minute to compute the sediment load. Total sediment load is expressed in pounds and in tons per square mile.

4. Area--Obtained from a topographic survey of the site. Expressed in square feet.

5. Weighted mean slope--Obtained by measuring the area between contours and weighting the slope of that area according to the percentage the area is of the whole.

6. Antecedent moisture--Obtained from gravimetric samples of the top 10 centimeters of soil. Samples are usually taken at four locations within the site and averaged for the final result. Expressed as percentage by weight. Two runs are normally made at each site. The first is made in a dry condition and again after water in the soil has come to a gravimetric equilibrium. Soil moisture samples are taken before each run.

7. Clay--Obtained from soil samples taken from the top 10 centimeters of soil at numerous locations within the site. Samples are analyzed for percentage by weight of material less than 0.002 millimeters in diameter.

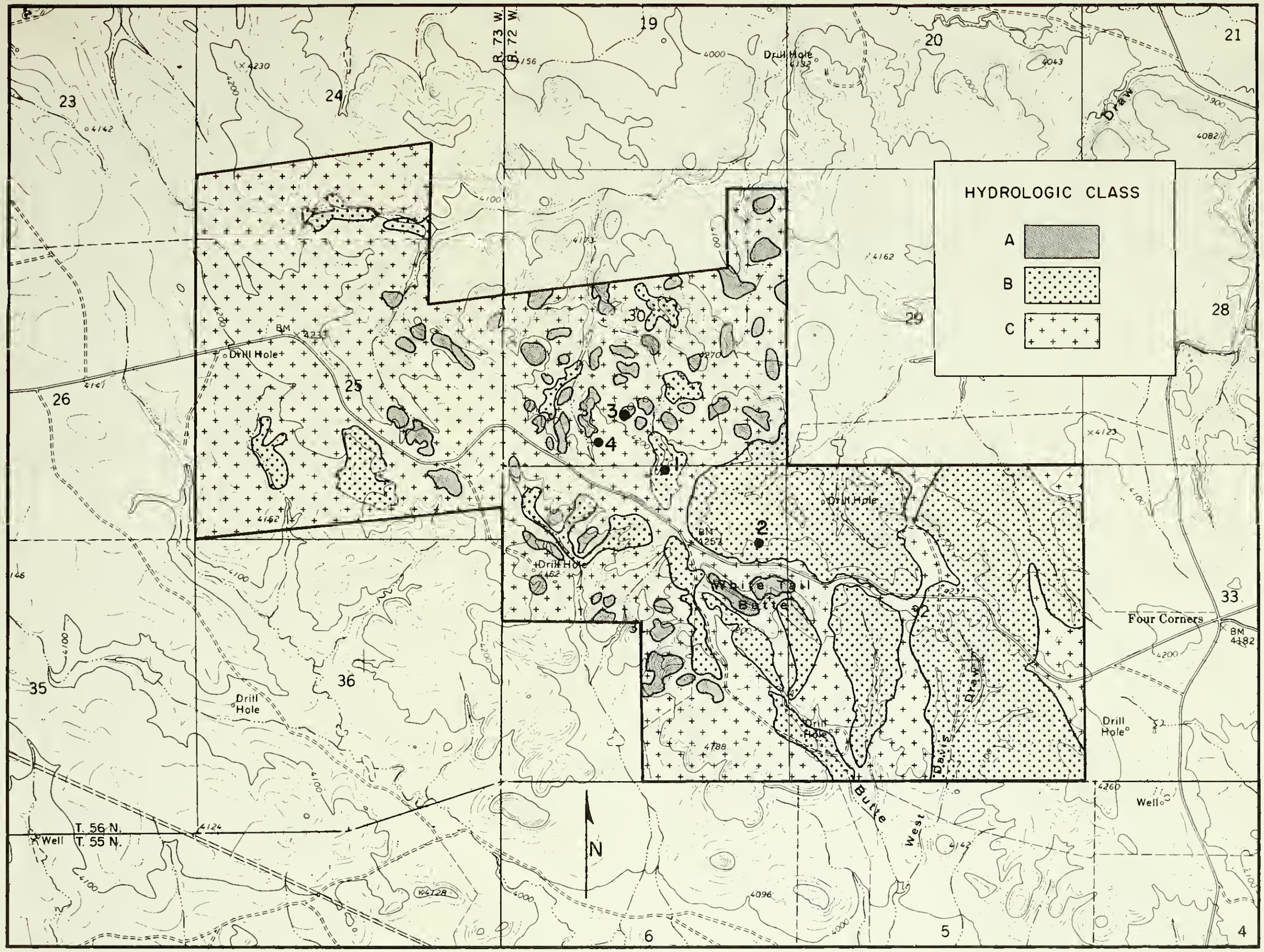
8. Root concentration--The amount of fibrous root material in the top 10 centimeters of soil. Expressed in grams per 100 grams of soil.

9. Bare soil and rock--Obtained from three 20-foot transects within each site using a point frame and the first contact point method. Pins lowered to the vegetation or ground surface at 2-inch intervals are recorded at first encountering of areal vegetation, mulch, bare soil or rock. Expressed as hits per 100 pins or percent cover.

10. Reconstructed runoff--Rainfall applied normally varies somewhat about the standard of 1.5 inches in 45 minutes. In order to compare runoff results on a standard basis, a runoff hydrograph is reconstructed by determining the runoff that would result from subtracting the infiltrated water determined during the simulation event from the water applied during a standard storm of 1.5 inches in 45 minutes for each minute increment.

## Chemical Analyses

Samples of the outflow from each site were obtained at 3-minute intervals for chemical analyses. These samples were composited in sequential groups so that three or four samples were obtained for the entire runoff period. An analysis was made on each composite sample for the items listed in Table 33. An analysis of the water applied is used as a standard, and other values listed are either an increase (+) or decrease (-) of these values in the runoff water.




Base from U.S. Geological Survey
White Tail Butte
7½-minute quadrangle

HYDROLOGIC CLASSIFICATION OF THE WHITE TAIL BUTTE,
WYOMING EMRIA STUDY AREA--1976

Figure 19.--Rainfall simulation on the White Tail Butte study area. Top photograph is site 1, middle is site 2, and bottom is site 4.

| Variable | Site | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-1 | 1-2 | 2-1 | 2-2 | 3-1 | 3-2 | 4-1 | 4-2 |
| Date | 8-19-76 | 8-20-76 | 8-22-76 | 8-23-76 | 8-17-76 | 8-18-76 | 8-12-76 | 8-13-76 |
| Area (sq. ft.) | 2,194 | 2,194 | 1,976 | 1,976 | 2,298 | 2,298 | 3,194 | 3,194 |
| Weighted mean slope (percent) | 9.5 | 9.5 | 15.9 | 15.9 | 18.4 | 18.4 | 6.1 | 6.1 |
| Antecedent moisture (percent) | 8.5 | 22.7 | 7.2 | 14.5 | 5.7 | 24.0 | 11.5 | 27.0 |
| Clay (percent) | 53.1 | 53.1 | 52.6 | 52.6 | 22.2 | 22.2 | 24.2 | 24.2 |
| Root concentration (g/100 g) | 2.628 | 2.628 | .848 | .848 | 2.484 | 2.484 | 1.206 | 1.206 |
| Bare soil and rock (percent) | 34.0 | 34.0 | 48.7 | 48.7 | 7.7 | 7.7 | 8.0 | 8.0 |
| Precipitation (inches) | 1.56 | 1.71 | 1.82 | 1.69 | 1.51 | 1.57 | 1.61 | 1.57 |
| Runoff (inches) | .69 | 1.05 | 1.01 | 1.01 | .03 | .05 | .40 | .67 |
| Sediment | | | | | | | | |
| pounds | 11.74 | 15.97 | 37.79 | 44.02 | .17 | .64 | 2.27 | 3.20 |
| tons per sq. mi. | 74.6 | 101 | 267 | 311 | 1.0 | 3.9 | 9.9 | 14.0 |
| Reconstructed runoff (inches) | .68 | .87 | .73 | .87 | .10 | .10 | .30 | .51 |

Table 32 Data obtained from simulation sites at White Tail Butte Study Area

(1 in second part of site designation indicates dry run, 2 indicates wet run)

Table 33

Changes in water chemistry (+ or -) of runoff water as compared to applied water

| Site | Composite | Variable | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Cations (mg/L) | | | | Anions (mg/L) | | | | | | Total Cations | Total Anions |
| | | pH | Specific Conduct. | Residue mg/L | Calcium | Magnesium | Potassium | Sodium | Bicarb. | Carbonate | Chloride | Flouride | Sulfate | $NO_2+NO_3$ | MEQ/L | MEQ/L |
| White Tail 1-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | + .1 | + 57 | +33 | + 6 | + .6 | +2.0 | +2.3 | +24 | 0 | +1.4 | +.1 | +1 | +1.3 | +.513 | + .551 |
| | 2 | + .2 | + 43 | +16 | + 4 | + .1 | +2.0 | + .1 | +17 | 0 | +1.3 | +.1 | -2 | + .3 | +.263 | + .302 |
| | 3 | + .2 | + 35 | +16 | + 3 | - .2 | +1.8 | + .3 | +23 | 0 | + .6 | +.1 | -1 | - .1 | +.192 | + .372 |
| White Tail 1-2 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .4 | + 56 | +26 | + 9 | + .8 | +2.0 | +1.2 | +21 | 0 | + .6 | +.1 | 0 | + .03 | +.568 | + .369 |
| | 2 | - .1 | + 47 | +22 | + 5 | + .1 | +1.4 | +1.0 | +25 | 0 | + .4 | +.1 | -1 | + .01 | +.337 | + .406 |
| | 3 | - .1 | + 36 | +14 | + 5 | + .3 | +2.0 | + .6 | +12 | 0 | 0 | +.1 | -1 | - .07 | +.331 | + .176 |
| White Tail 2-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .2 | +131 | +70 | +19 | +3.3 | +5.0 | + .5 | +61 | 0 | +4.2 | +.1 | +4 | + .28 | 1.369 | +1.227 |
| | 2 | 0 | + 81 | +38 | +13 | +1.7 | +1.3 | + .2 | +39 | 0 | + .4 | +.1 | 0 | + .01 | +.830 | + .657 |
| | 3 | 0 | + 68 | +31 | +11 | +1.1 | +1.5 | + .2 | +32 | 0 | + .6 | +.1 | +1 | 0 | +.686 | + .536 |
| White Tail 2-2 | Applied | 7.5 | +208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .1 | + 99 | +54 | +13 | +3.0 | +1.7 | + .5 | +51 | 0 | + .6 | +.1 | +7 | + .04 | +.960 | +1.007 |
| | 2 | + .1 | + 67 | +37 | + 9 | +1.7 | +1.2 | + .7 | +41 | 0 | + .3 | +.1 | +1 | + .01 | +.650 | + .707 |
| | 3 | + .1 | + 62 | +27 | + 8 | +1.5 | + .9 | + .6 | +29 | 0 | + .1 | +.1 | -1 | - .01 | +.571 | + .462 |
| White Tail 3-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | -1.0 | - 8 | - 4 | - 5 | - .6 | +4.0 | + .6 | -20 | 0 | +2.1 | 0 | +1 | + .41 | -.171 | - .218 |
| | 2 | - .8 | - 9 | - 7 | - 5 | - .3 | +4.0 | - .2 | -17 | 0 | + .8 | 0 | 0 | + .15 | -.181 | - .245 |
| | 3 | - .5 | + 2 | - 5 | - 5 | - .5 | +3.0 | + .1 | -10 | 0 | + .8 | +.1 | +1 | + .01 | -.210 | - .114 |
| White Tail 3-2 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .8 | + 17 | +15 | -1 | + .5 | +2.0 | +1.1 | 0 | 0 | + .9 | +.1 | +1 | +1.8 | +.090 | + .179 |
| | 2 | - .3 | + 12 | + 4 | -1 | - .1 | +1.8 | + .5 | + 1 | 0 | + .3 | +.1 | -1 | + .16 | +.009 | + .021 |
| | 3 | - .2 | + 15 | + 4 | -1 | - .1 | +1.6 | + .2 | + 1 | 0 | + .1 | +.1 | 0 | + .39 | -.009 | + .052 |
| White Tail 4-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | -1.0 | + 13 | +12 | -2 | +1.0 | +3.0 | +2.1 | - 1 | 0 | +1.6 | 0 | +4 | + .30 | +.150 | + .133 |
| | 2 | - .4 | + 9 | 0 | -2 | 0 | +2.0 | + .3 | - 2 | 0 | + .5 | 0 | 0 | + .01 | -.036 | - .018 |
| | 3 | - .3 | + 6 | - 1 | -1 | - .1 | +1.0 | 0 | - 2 | 0 | + .1 | 0 | 0 | - .04 | -.033 | - .033 |
| White Tail 4-2 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .1 | + 14 | + 4 | -1 | 0 | +1.8 | + .1 | 0 | 0 | + .3 | 0 | +2 | + .05 | -.008 | + .054 |
| | 2 | - .1 | + 8 | + 3 | 0 | - .1 | +1.5 | 0 | 0 | 0 | + .3 | +.1 | 0 | + .01 | +.030 | + .014 |
| | 3 | - .2 | + 7 | +17 | 0 | + .5 | +1.3 | + .3 | + 4 | 0 | +1.1 | +.1 | +3 | +1.4 | +.087 | + .271 |
| | 4 | - .1 | + 8 | + 6 | 0 | + .4 | +1.4 | + .3 | + 2 | 0 | + .3 | +.1 | -2 | + .25 | +.081 | + .023 |

## Precipitation

A frequency of recurrence of maximum daily precipitation during the months April through October at Gillette, Wyoming, is shown on Figure 20. From this curve, the following data on the magnitude of storms of various recurrence intervals were obtained. These data give a general idea of storms in the vicinity of the study area.

| Recurrence interval (years) | Precipitation (inches) |
|---|---|
| 2.33 | 1.71 |
| 10.00 | 2.74 |
| 25.00 | 3.19 |
| 50.00 | 3.77 |

A description of each simulation site and of each hydrologic class follows. A list of precipitation events of different recurrence intervals and durations that were obtained from Weather Bureau Technical Paper 40 are also shown for each site. The volume of runoff that might be expected from storms of this type was computed using infiltration rates obtained from the dry-condition simulation events.

## Hydrologic Class A

This class consists of the tops of numerous small conical-shaped hills in the study area. The underlying material is made up of clinker which is very permeable. No appreciable increase in runoff was noted after the soil had been wetted. The following data was obtained from the simulation site.

Weighted mean slope = 18.4 percent
Clay = 22.2 percent
Bare soil and rock = 7.7 percent

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

| RI/D/M | AM = 5.7 | AM = 24.0 |
|---|---|---|
| 2/30/0.60 | 0.00 | 0.00 |
| 10/30/1.05 | 0.08 | 0.08 |
| 25/30/1.30 | 0.29 | 0.36 |
| 50/30/1.50 | 0.35 | 0.54 |
| 2/60/0.80 | 0.00 | 0.00 |
| 10/60/1.30 | 0.00 | 0.00 |
| 25/60/1.60 | 0.00 | 0.00 |
| 50/60/1.80 | 0.00 | 0.00 |

## Hydrologic Class B

This class occurs on parts of the study area that have been eroded into the underlying formation. Clay content of the soil is generally greater than 50 percent and bare soil and rock make up a large part of the surface. This class probably produces most of the sediment derived from the area. The following data was obtained from the simulation sites.

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

### Class B - site 1

Weighted mean slope = 9.5 percent
Clay = 53.1 percent
Bare soil and rock = 34.0 percent

| RI/D/M | AM = 8.5 | AM = 22.7 |
|---|---|---|
| 2/30/0.60 | 0.06 | 0.15 |
| 10/30/1.05 | 0.41 | 0.56 |
| 25/30/1.30 | 0.60 | 0.81 |
| 50/30/1.50 | 0.78 | 1.02 |
| 2/60/0.80 | 0.02 | 0.11 |
| 10/60/1.30 | 0.37 | 0.52 |
| 25/60/1.60 | 0.61 | 0.80 |
| 50/60/1.80 | 0.80 | 0.99 |

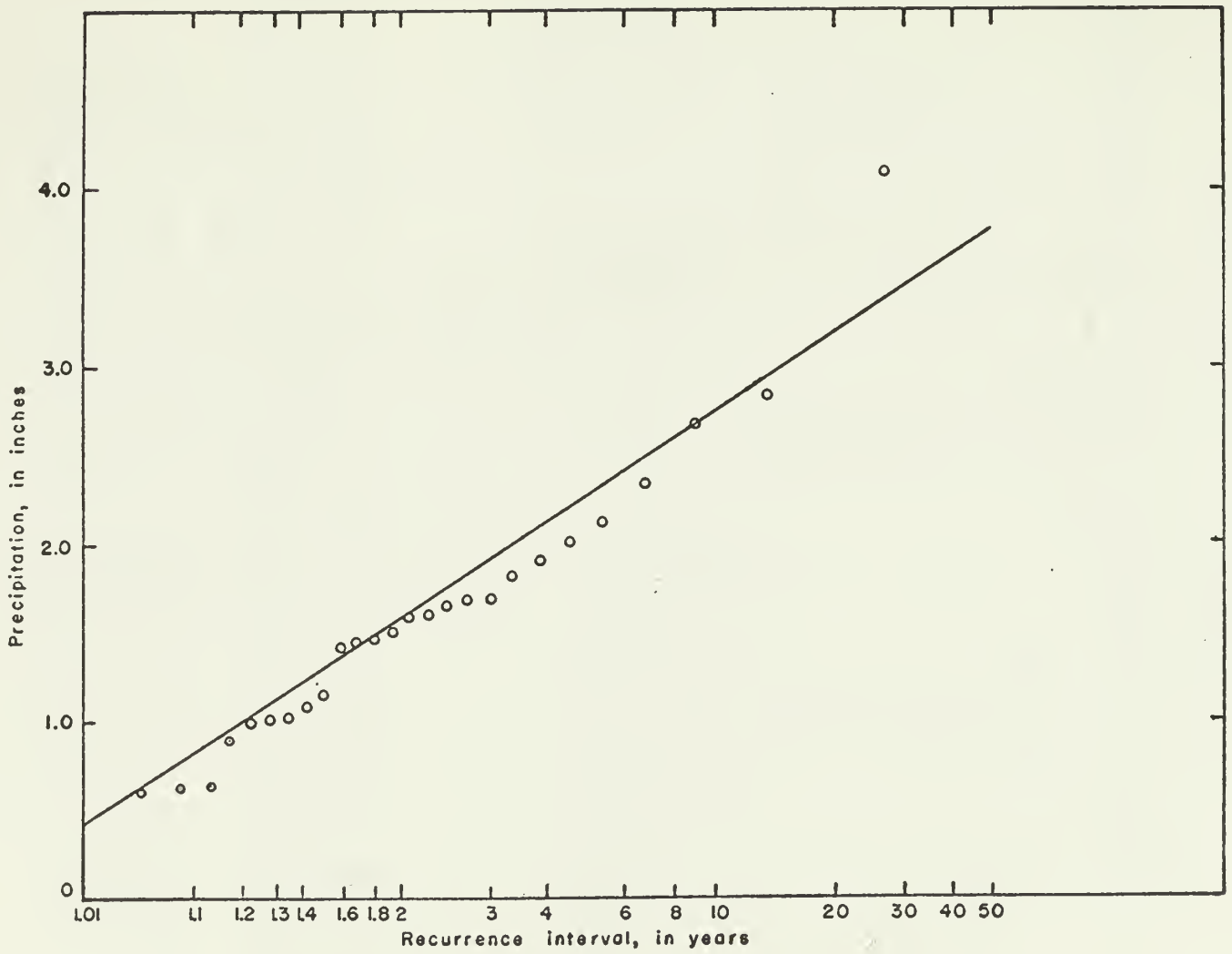
### Class B - site 2

Weighted mean slope = 15.9 percent
Clay = 52.6 percent
Bare soil and rock = 48.7 percent

| RI/D/M | AM = 7.2 | AM = 14.5 |
|---|---|---|
| 2/30/0.60 | 0.11 | 0.19 |
| 10/30/1.05 | 0.48 | 0.59 |
| 25/30/1.30 | 0.69 | 0.82 |
| 50/30/1.50 | 0.89 | 1.02 |
| 2/60/0.80 | 0.04 | 0.05 |
| 10/60/1.30 | 0.41 | 0.48 |
| 25/60/1.60 | 0.71 | 0.77 |
| 50/60/1.80 | 0.89 | 0.97 |

## Hydrologic Class C

This class supports an excellent stand of grass which inhibits erosion even though runoff is fairly high. It is contained in many of the grassy swales which show no sign of cutting and actually may be aggrading. Slopes




Recurrence of maximum yearly 24-hour rainfall (Apr-Oct) at Gillette, Wyo.

Figure 20

range from almost flat to fairly steep on some of the well-vegetated hillsides. The following data was obtained from the simulation site.

| | | |
|---|---|---|
| Weighted mean slope | = | 6.1 percent |
| Clay | = | 24.2 percent |
| Bare soil and rock | = | 8.0 percent |

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

| RI/D/M | AM = 11.5 | AM = 27.0 |
|---|---|---|
| 2/30/0.60 | 0.00 | 0.00 |
| 10/30/1.05 | 0.18 | 0.34 |
| 25/30/1.30 | 0.37 | 0.57 |
| 50/30/1.50 | 0.58 | 0.80 |
| 2/60/0.80 | 0.00 | 0.00 |
| 10/60/1.30 | 0.00 | 0.12 |
| 25/60/1.60 | 0.14 | 0.35 |
| 50/60/1.80 | 0.30 | 0.55 |

## Runoff, Infiltration Rates, and Sediment Concentration

The curves for runoff, sediment concentration, and infiltration rates for the simulation sites are shown in Figures 21 through 28. The horizontal part of the infiltration curve indicates that the actual infiltration rate exceeded the rainfall rate. Water discharge is in cubic feet per second and sediment concentration in milligrams per liter.

## Surface Water Hydrology

### Description of Small Basins

North Divide Draw drains 1.72 $mi^2$ of the rugged upland divide between Elk Creek to the north and Whitetail Creek to the south. Altitudes range from 3,907 feet at the outlet of the basin to 4,345 feet on top of White Tail Butte. Clayey soils, developed from the Fort Union, are relatively impermeable. A large part of the lower basin is covered with exposed, permeable clinker. Figure 29 is a three-dimensional sketch of the basin.

Elk Creek tributary, which adjoins North Divide Draw on the east, drains an area of 2.10 $mi^2$. The terrain and soils are similar to North Divide Draw, except for a large, flat, upland area in the western part if the basin. Table 34 lists the physical characteristics of the two drainages. Figure 30 is a three-dimensional sketch of Elk Creek tributary.

Table 34 - Physical Basin Characteristics

| Site | Drainage area ($mi^2$) | Basin slope (ft/mi) | Channel slope (ft/mi) | Maximum relief (ft) | Orientation (degree) | Exposed clinker (percent) |
|---|---|---|---|---|---|---|
| North Divide Draw | 1.72 | 904 | 78.0 | 438 | 30 | 37 |
| Elk Creek tributary | 2.10 | 899 | 96.3 | 334 | 80 | 51 |

## Data Collection

Data collection began with the installation of stage and rainfall recorders in June and July 1976. A dual stage-rainfall recorder was installed in the channel at the outlets of North Divide Draw and Elk Creek tributary near Recluse, Wyoming. Three additional rain gages were installed near the headwaters of the two basins. Figure 31 shows the location of instrumentation used in this study.

The ephemeral nature of these two streams makes it almost impossible to be present at the time of peak flows. Therefore, stage-discharge relations were developed using step-backwater methods for high flow and current-meter measurements for low flow.

Chemical-quality and sediment samples were collected at low flows and by single-stage sediment samplers at preset stages. Samples collected by the samplers were submitted to the sediment laboratory for analysis, provided the samplers had functioned properly.

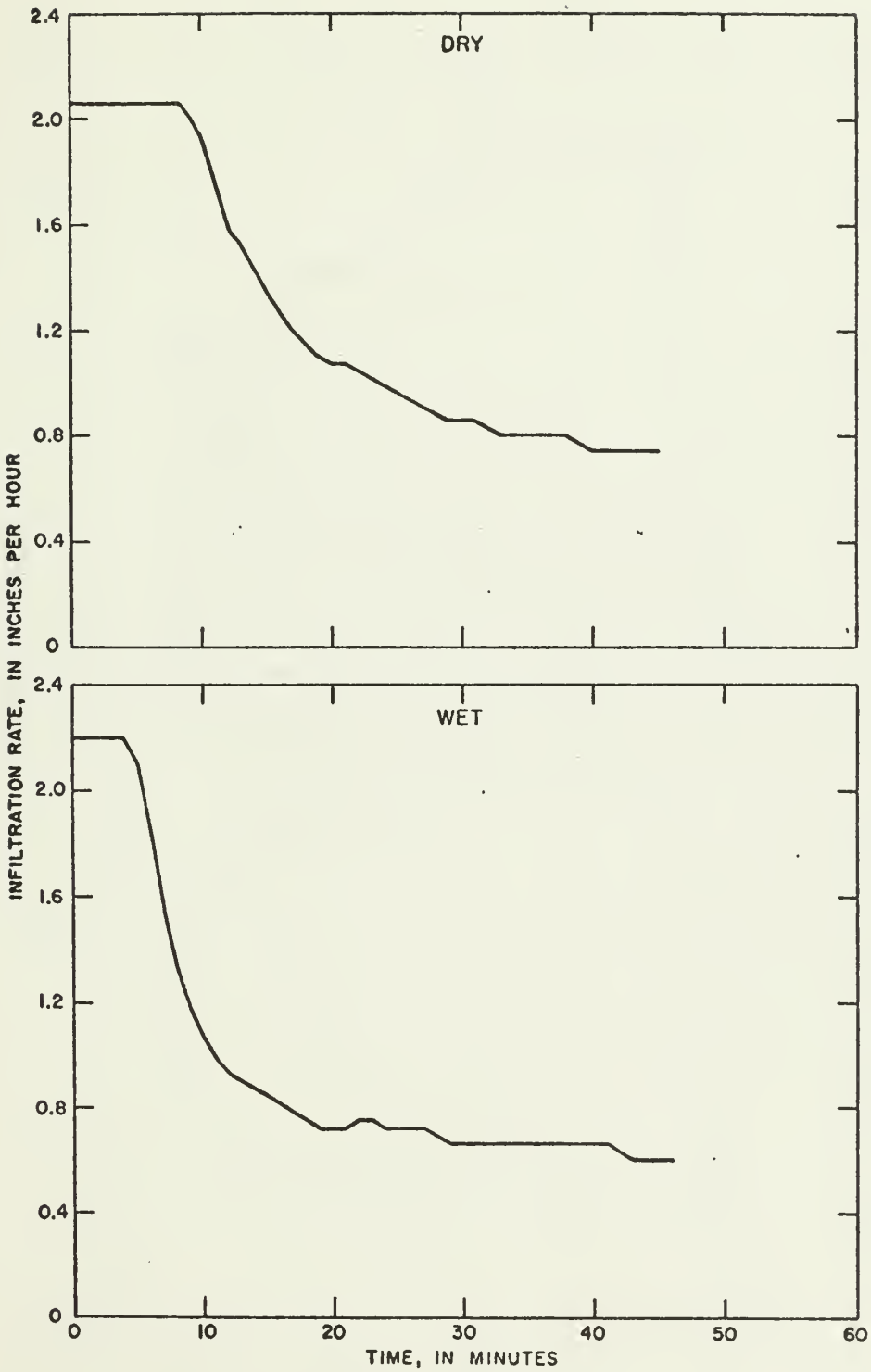
Data collection was discontinued in late August 1977 when the stage and rainfall recorders were removed. Reference marks and staff gages were left for future reference at the outlet of each basin.

## Runoff

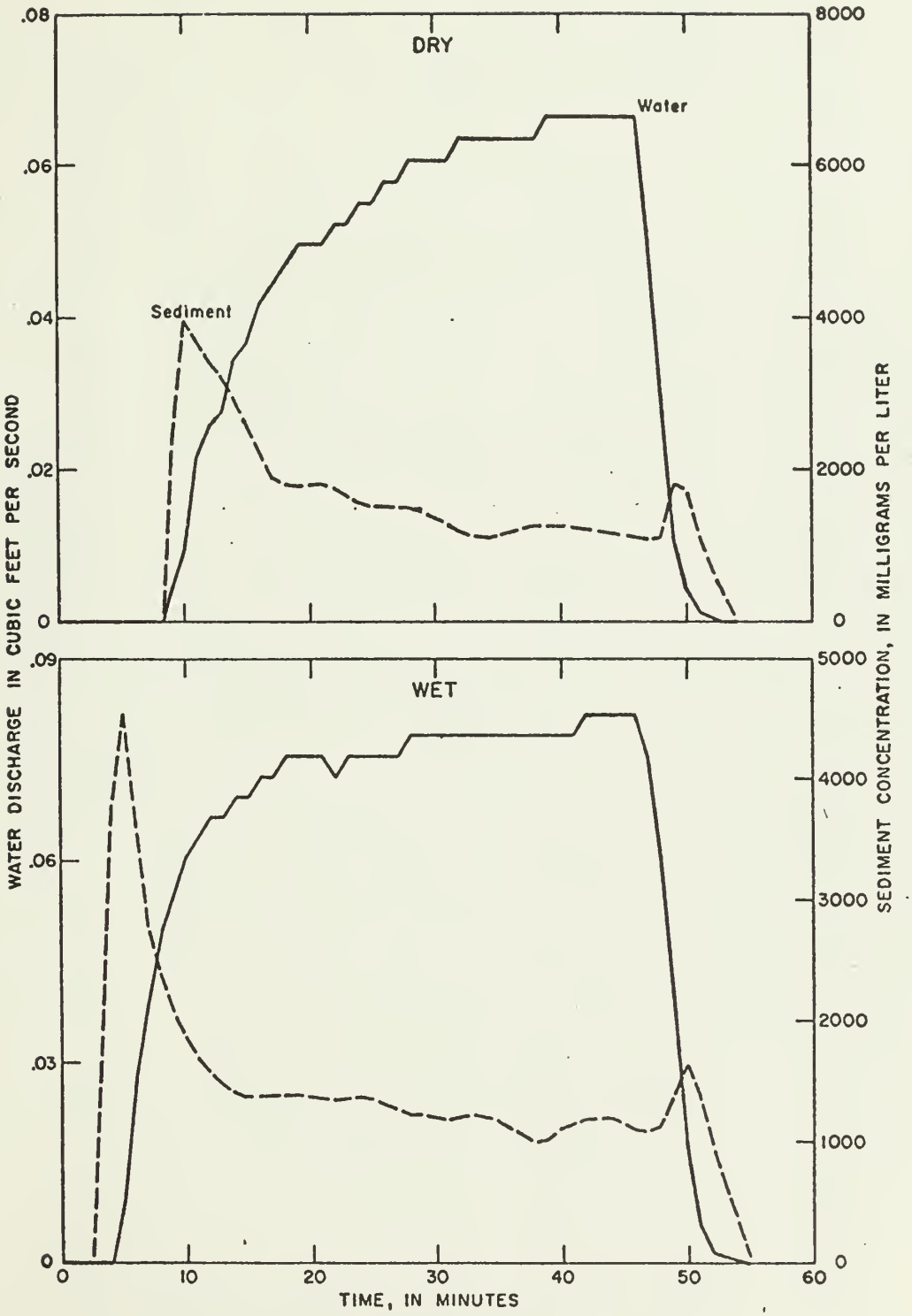
Total runoff from North Divide Draw for a one-year period from June 24, 1976, to June 23, 1977, was 61.0 acre-ft. Elk Creek tributary had a total runoff of 19.2 acre-ft from July 9, 1976, to July 8, 1977. Missing record due to recorder malfunction was estimated using high-water marks, range-in-stage records, and precipitation records from nearby stations.

A snow survey was conducted on January 18, 1977, at two sites in the North Divide drainage basin. The upper site, located near the upper rain gage, had an average snow depth of 9.8 inches, and the lower site, near the stage gage, had an average snow depth of 13.0 inches. The moisture content was 23 percent by volume. Estimated moisture available for runoff on January 18, 1977, from North Divide Draw was 2.6 inches (240 acre-ft). A similar snow pack could be expected on the Elk Creek tributary basin.

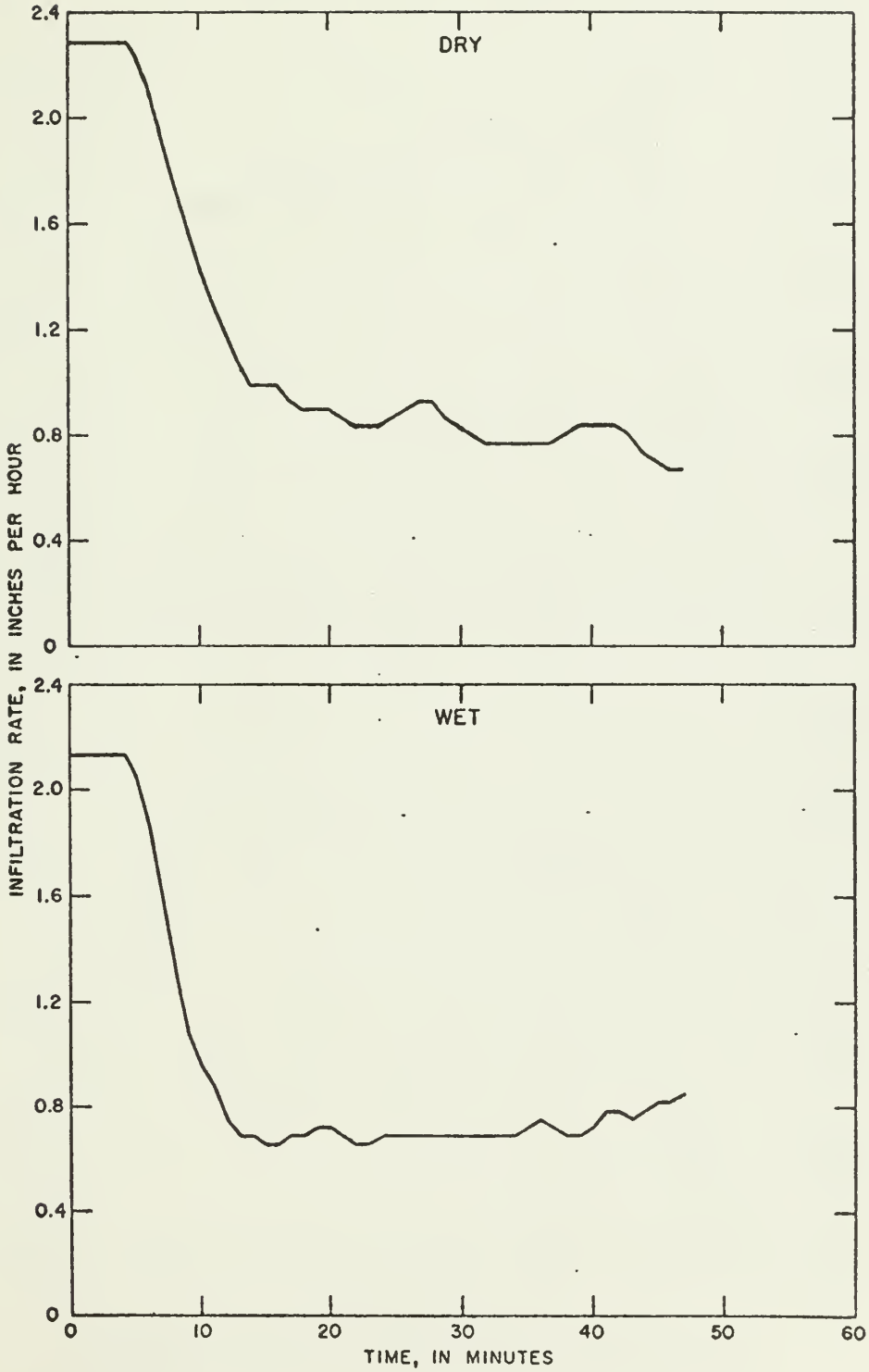
Snowmelt runoff occurred on April 5 and 6, 1977. The runoff from snowmelt in the North Divide Draw basin was estimated at 3.2 acre-ft, or about



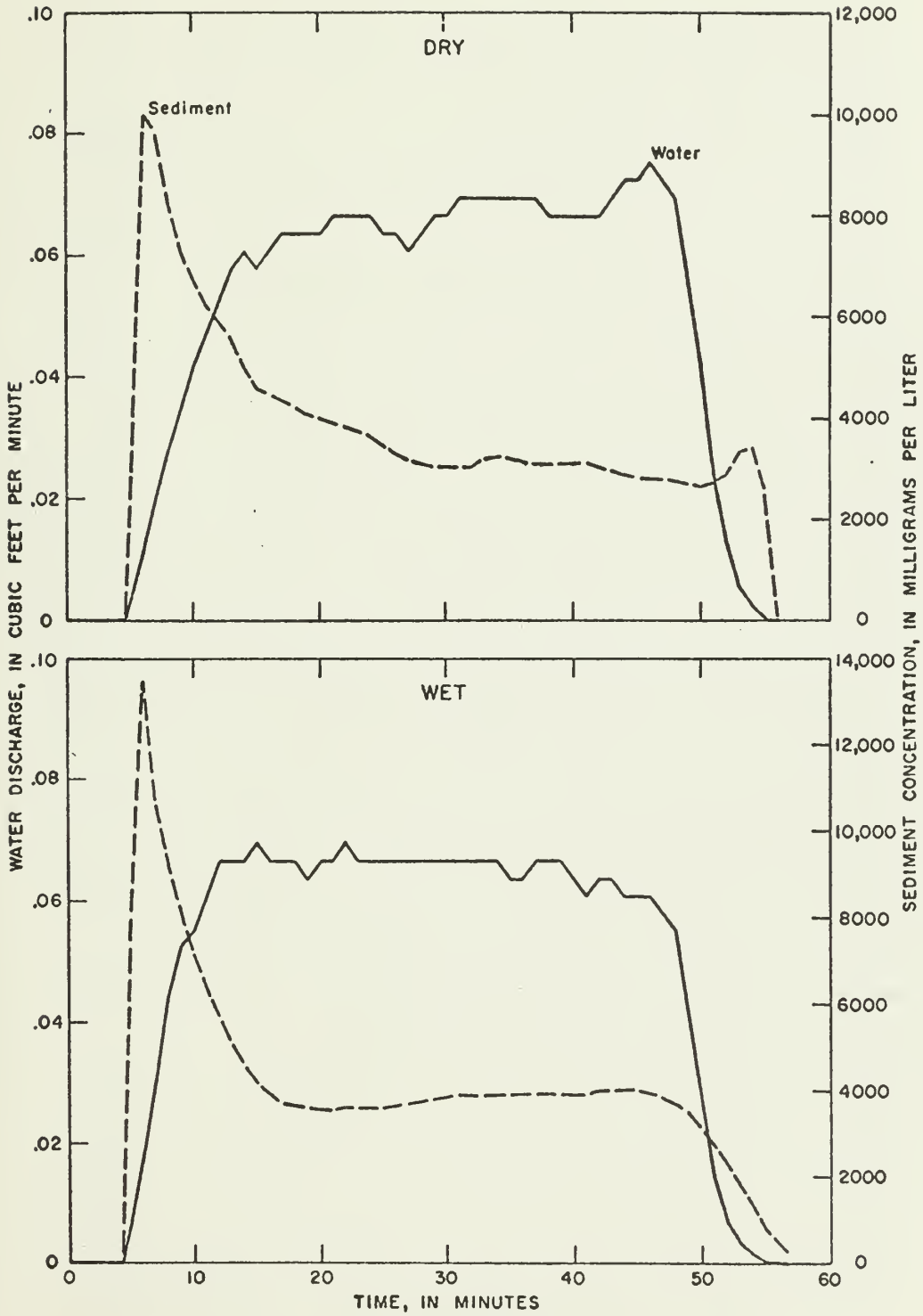

Infiltration curves for site 1.



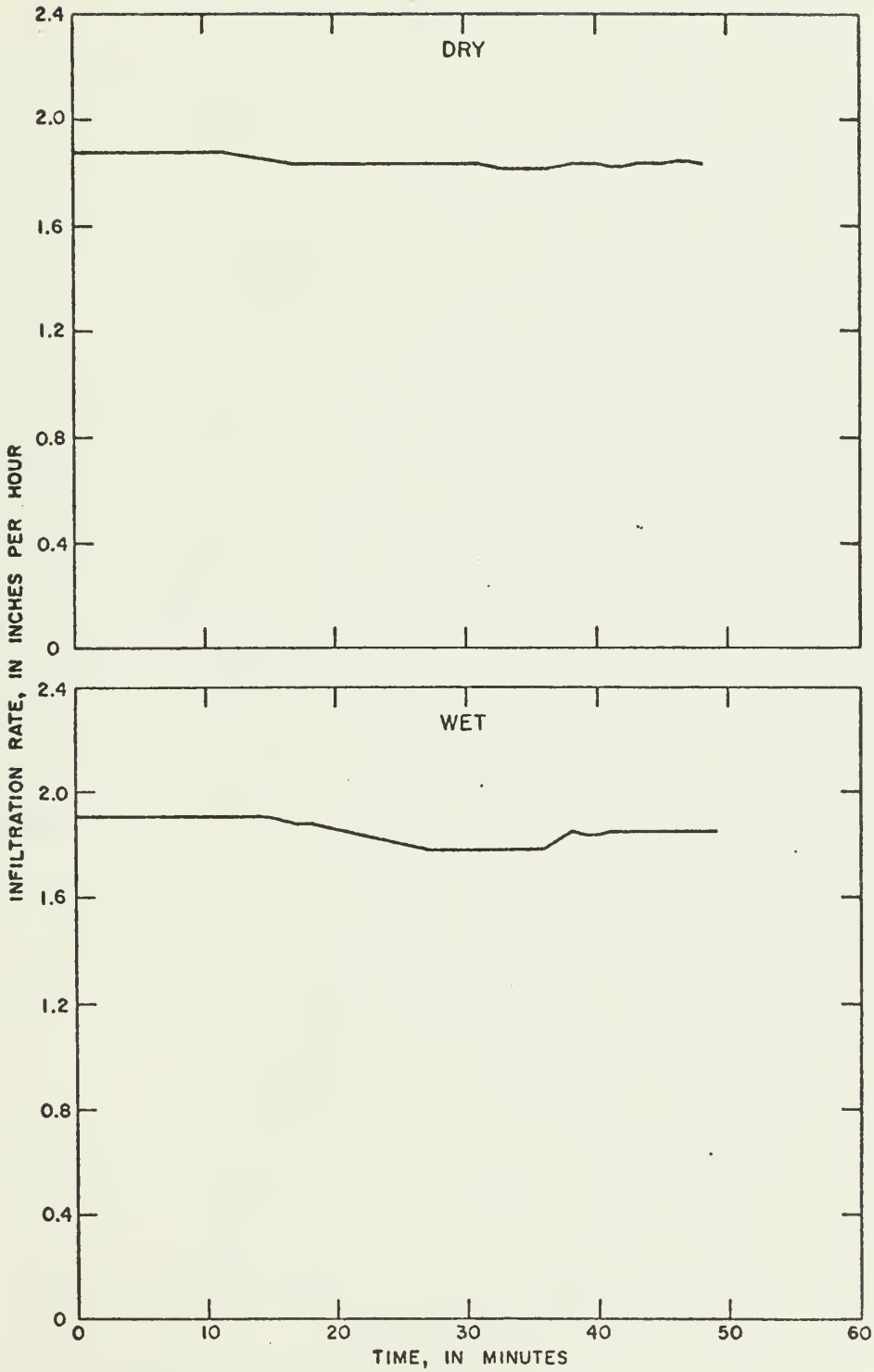

Runoff and sediment concentration curves for site 1.



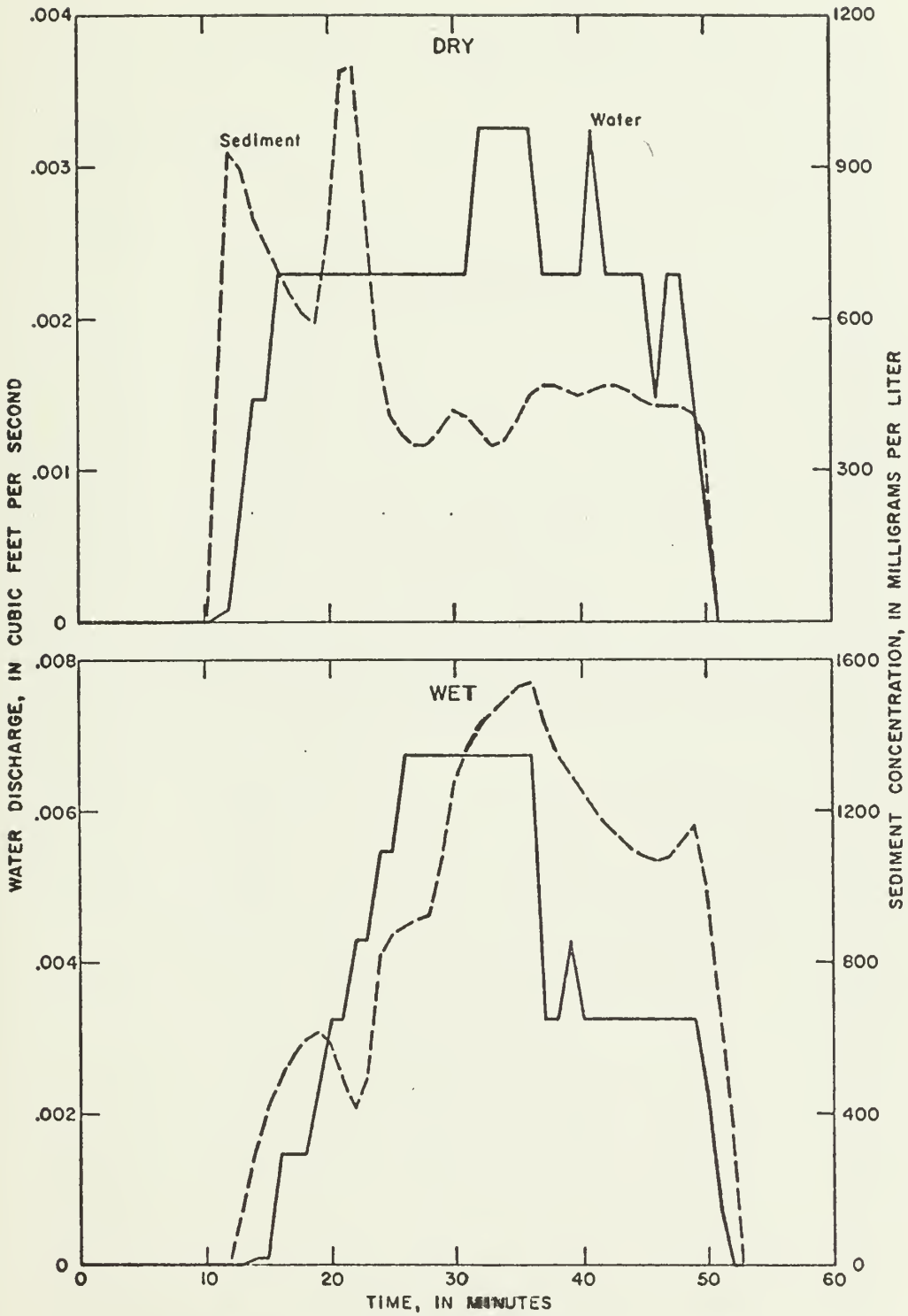

-Infiltration curves for site 2.



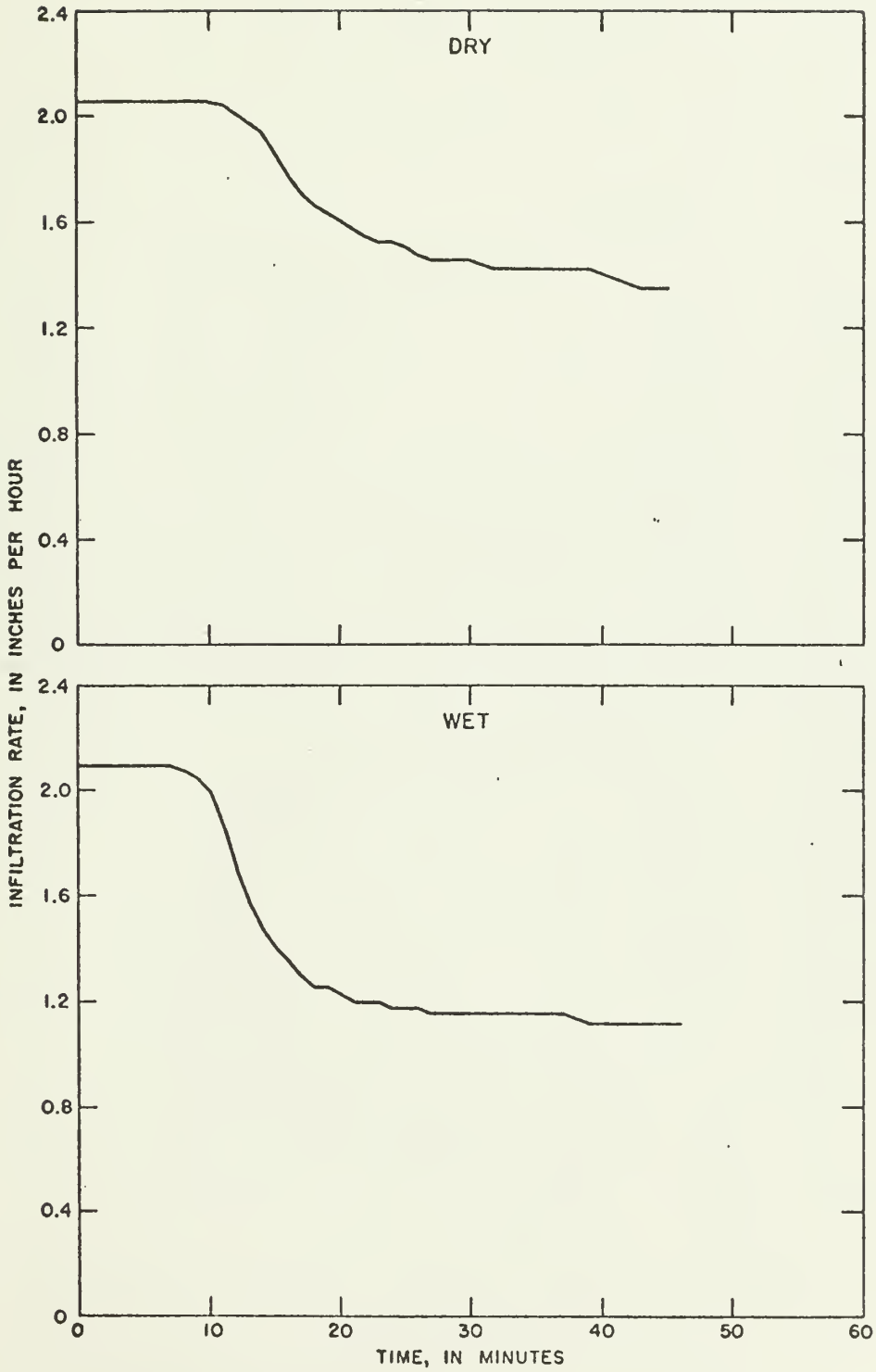

Runoff and sediment concentration curves for site 2.



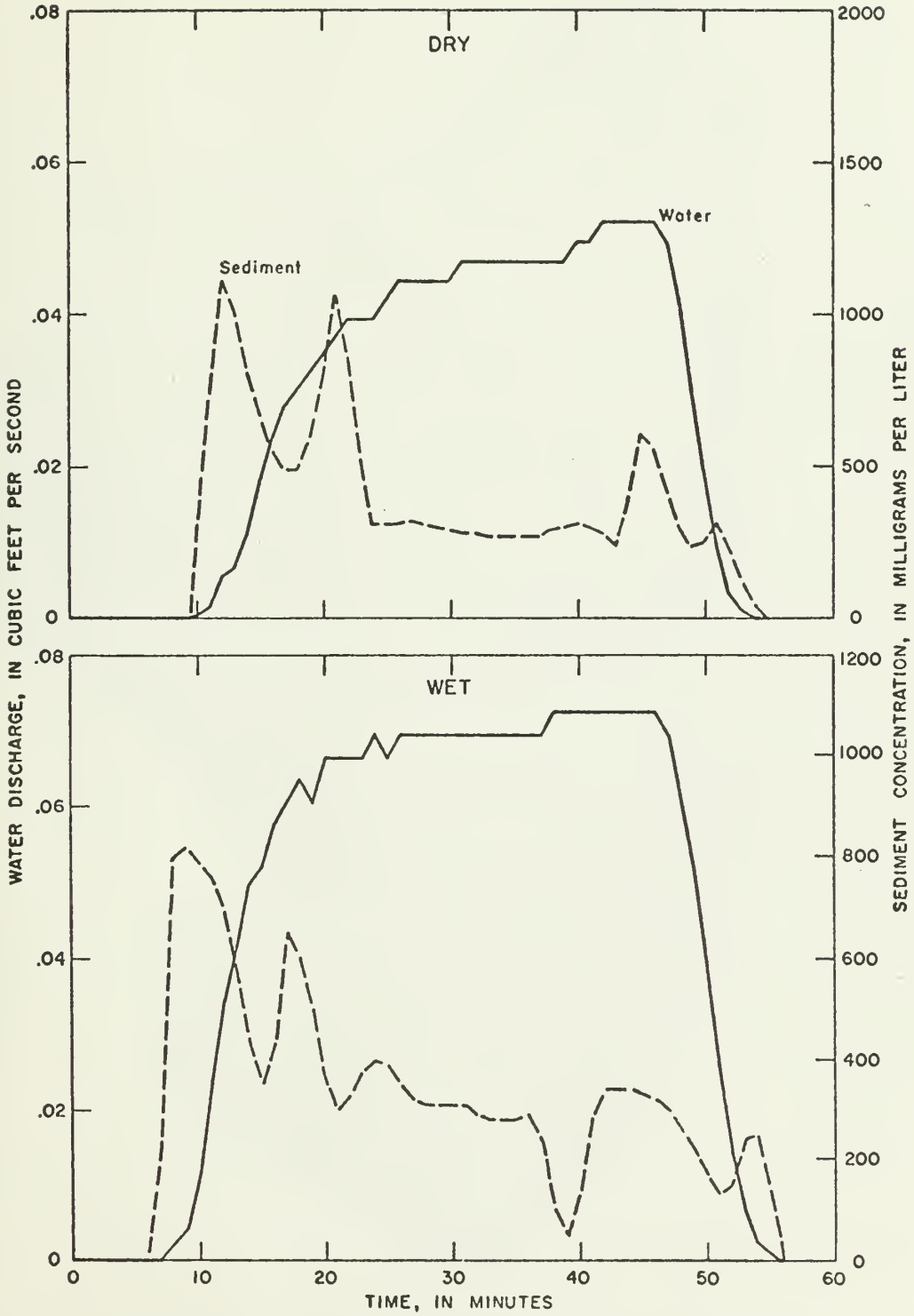

Infiltration curves for site 3.




Runoff and sediment concentration curves for site 3.




Infiltration curves for site 4.




Runoff and sediment concentration curves for site 4.

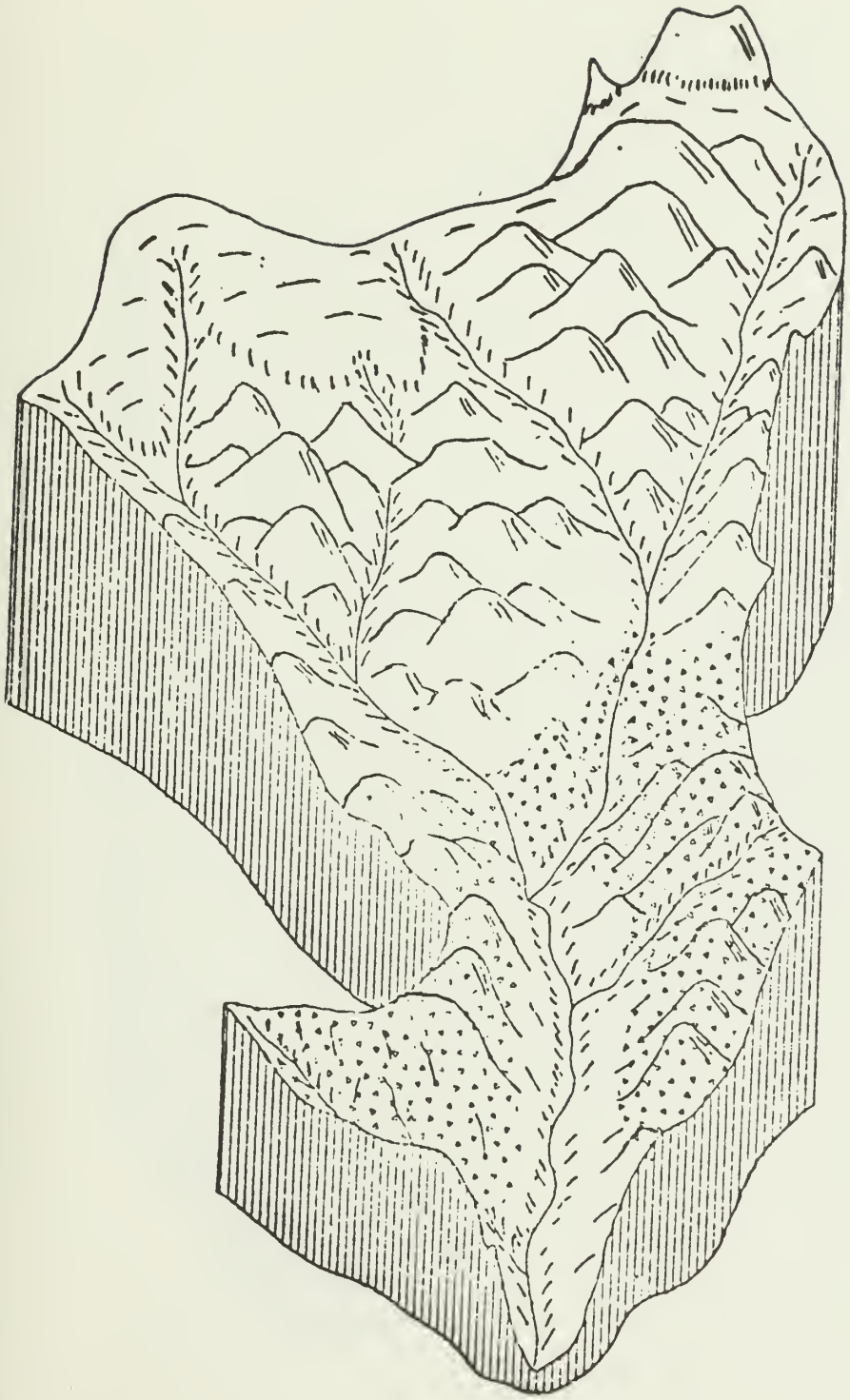


Figure 29 Sketch of North Divide Draw near Recluse, Wyoming. Area of exposed clinker is patterned.

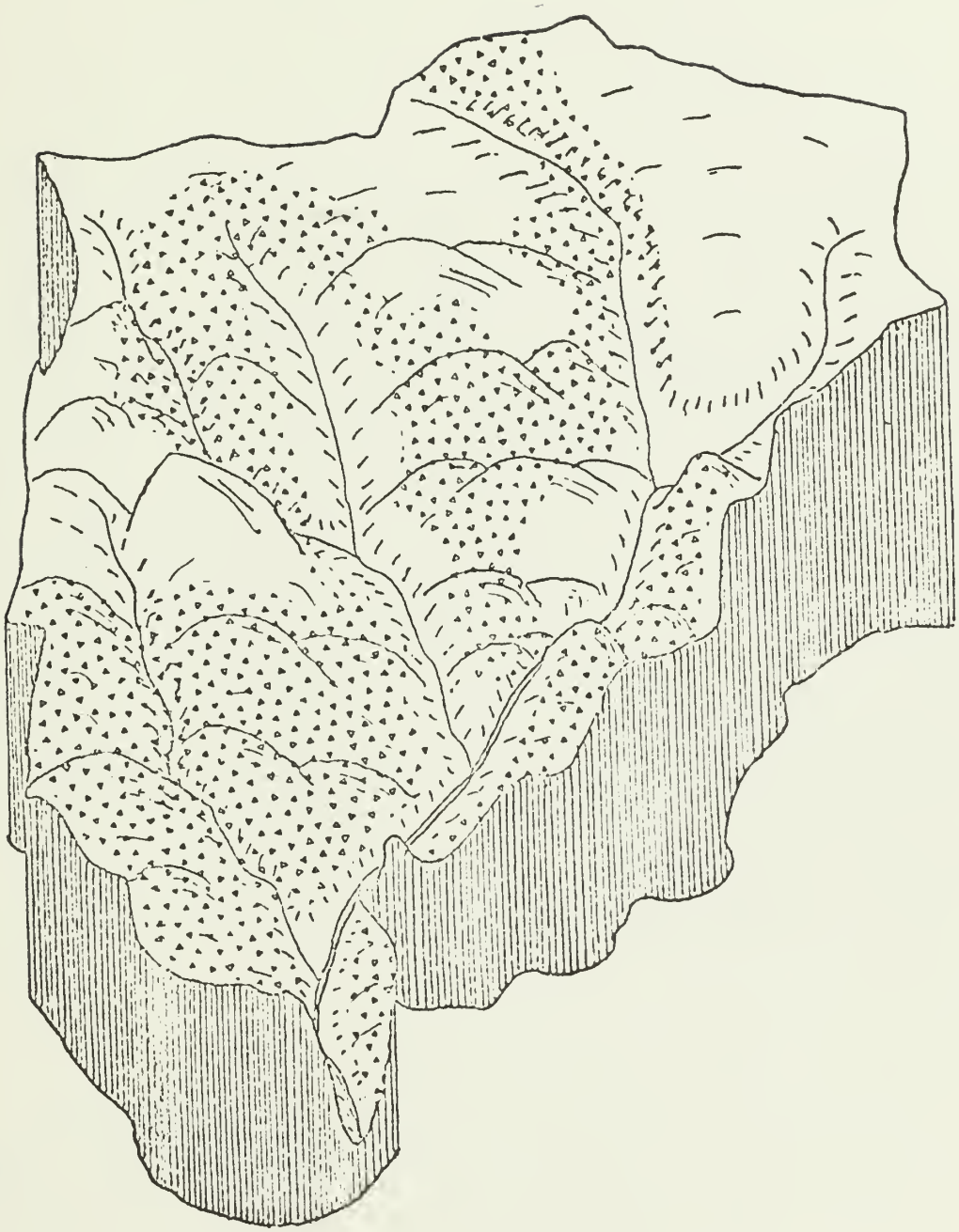
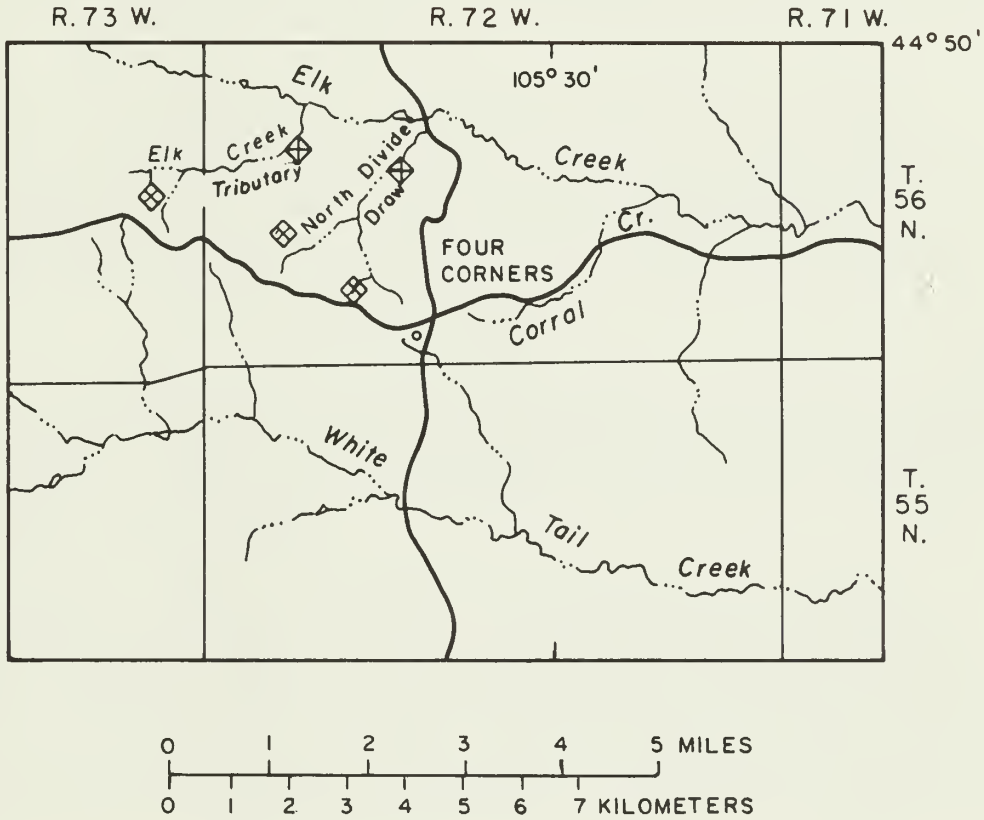


Figure 30 Sketch of Elk Creek Tributary near Recluse, Wyoming. Area of exposed clinker is patterned.




EXPLANATION

Stage Rainfall Gage

Rain Gage

Instrumentation for surface-water studies.

5 percent of the total runoff for the period June 24, 1976, to June 23, 1977. The estimate was based on the peak discharge (1.6 $ft^3/s$), observation by the authors, and the temperature record at Recluse, Wyoming. Total snowmelt runoff on Elk Creek tributary was 0.2 acre-ft.

Runoff from convective storms produced 58 acre-ft during the one-year period, or 95 percent of the total runoff from North Divide Draw. Rainfall produced 19 acre-ft of runoff, almost 100 percent of the runoff on Elk Creek tributary. The largest runoff event, peak and volume, for both basins occurred on June 12, 1977. Figure 32 shows the hydrographs and the cumulative rainfall which produced the runoff events.

Craig and Rankl (1978) established a relationship between the volume of a runoff resulting from convective storms on small ephemeral streams and the maximum discharge. This relationship is useful for design purposes to determine the volume of runoff for a stream where the peak discharge is known. The peak-volume relationship developed for North Divide Draw and Elk Creek tributary near Recluse, Wyoming, is shown in Figures 33 and 34.

## Flow-Frequency Analysis

The magnitude and frequency of peaks and runoff volumes are flow characteristics which are required for the design of storage reservoirs, hydraulic structures, and channel relocation. These flow characteristics can be used to establish baseline conditions prior to a possible hydrologic change, such as a change that may result from strip mining.

Statistical analysis of long-term records of streamflow can be used to determine the desired flow characteristics, or the information can be computed from regional flow-frequency analysis using either basin or channel characteristics. Because long-term flow records were not available for the study sites and the regional flow-frequency investigations did not include basins with large areas of surface clinker, it was decided to collect short-term rainfall-runoff data, calibrate basin models, and extend the records using long-term weather records.

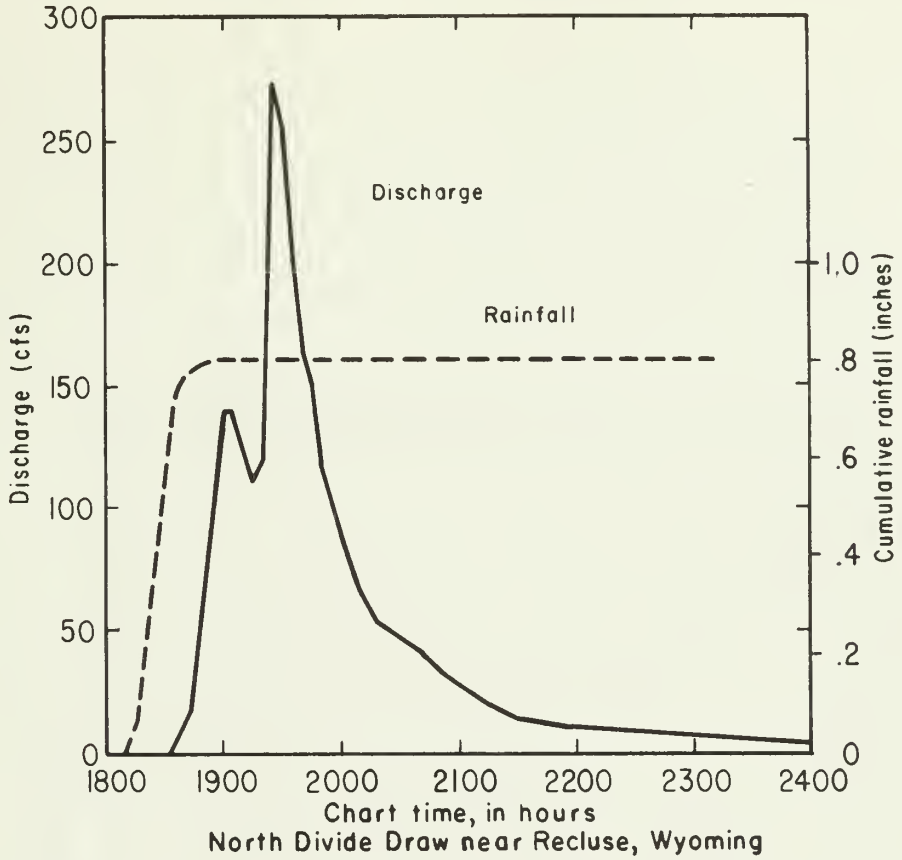
## Rainfall-Runoff Model

A digital rainfall-runoff model developed by Dawdy and others (1972) and modified by Craig and Rankl (1978) was used in this study. This model uses three parameters for infiltration evaluation, four for soil-moisture accounting, three to account for variation of infiltration with time, and three flow-routing parameters. The following table lists the model parameters, their function, and their application. The objective function, which is the sum of the squared errors divided by the number of events, is minimized to obtain the best fit of the parameters.

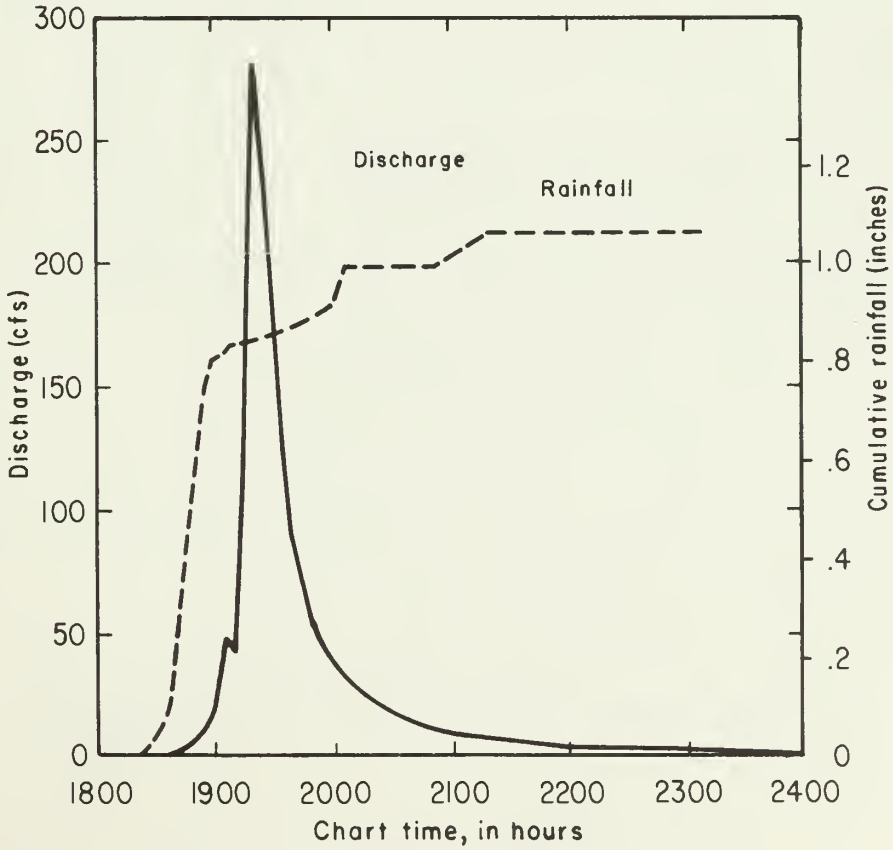
Rainfall-runoff model parameters, their function, and application

| Parameter | Units | Function | Application |
|---|---|---|---|
| PSP | Inches | Infiltration | Suction at the wetted front for soil moisture at field capacity. |
| RGF | ---- | do | Ratio of the suction at the wetted front for soil moisture at wilting point to that at field capacity. |
| KSAT | Inches, per hr | Infiltration | The minimum saturated value of hydraulic conductivity used to determine infiltration soil rates. |
| BMSM | Inches | Moisture accounting | Soil moisture-storage volume at capacity |
| EVC | ---- | do | Coefficient to convert pan evaporation to potential evapotranspiration values. |
| DRN | Inches, per hr | do | A constant drainage rate for redistribution of soil moisture. |
| RR | ---- | do | Proportion of daily rainfall that infiltrates the soil. |
| CKMX | ---- | Variation of infiltration with time | Exponent which sets the maximum potential infiltration rate in a given year. |
| CKMN | ---- | do | Exponent which sets the minimum potential infiltration rate in a given year. |
| CKEX | ---- | do | Controls the rate of decay between CKMX and CKMN. |
| KSW | Hours | Overland flow | Time-storage characteristic for linear reservoir routing. |
| TC | Minutes | do | Time of concentration for the time-discharge histogram. |
| TP | Minutes | do | Time to peak for the time-discharge histogram. |

Note: Expanded from a table by Dawdy and others (1972).

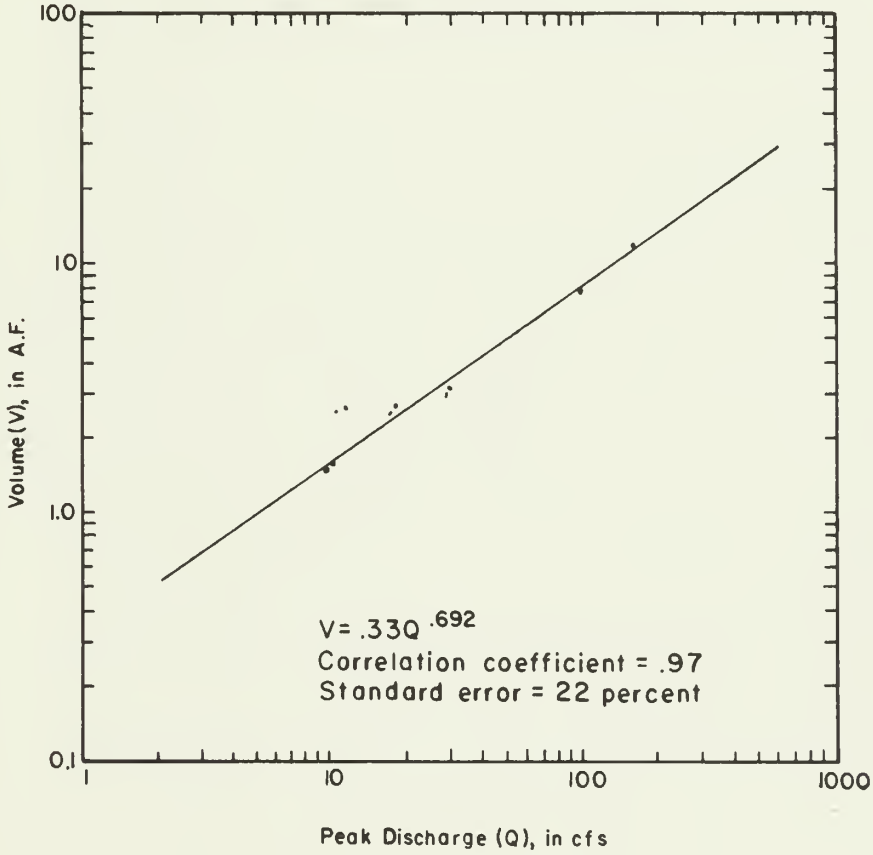



North Divide Draw near Recluse, Wyoming

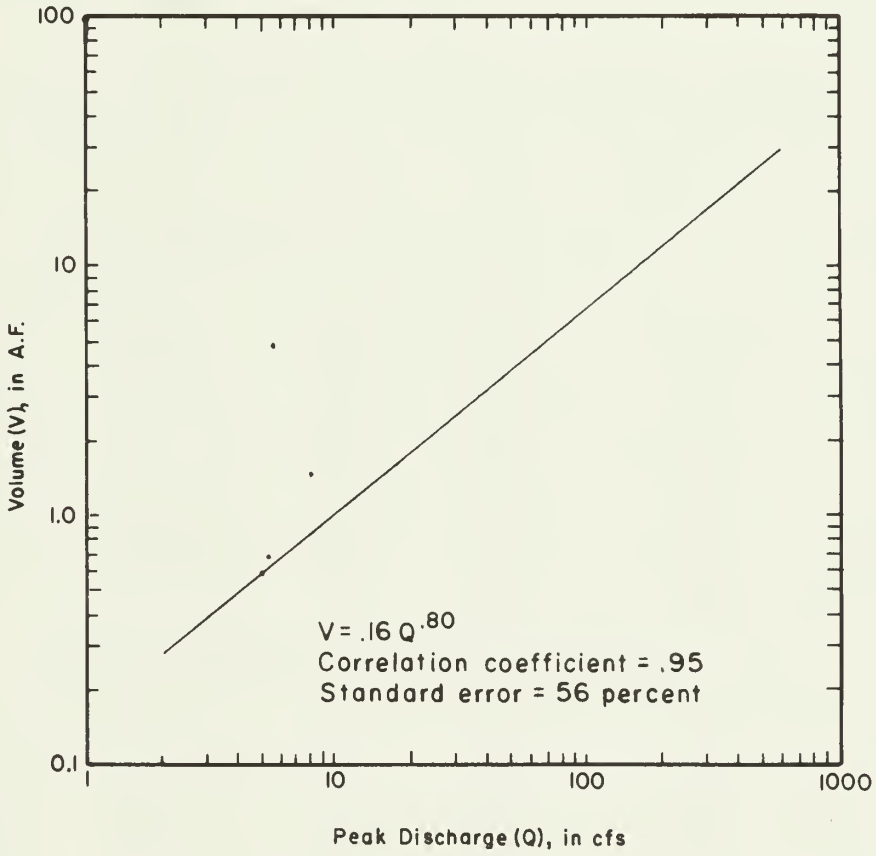



Elk Creek Tributary near Recluse, Wyoming

Maximum runoff events for basins used in runoff investigations
June 12, 1977




Peak-volume relation for North Divide Draw near Recluse, Wyoming.




Peak-volume relation for Elk Creek tributary near Recluse, Wyoming.

An in-depth discussion of the model parameters, derivations, and functions are in Dawdy and others (1972). Modifications of the model for semiarid conditions are discussed by Craig and Rankl (1978).

## Calibration

North Divide Draw had ten runoff-producing rains that provided data for calibration of the digital model, and Elk Creek tributary had six. The following table lists the date, total rainfall, peak discharge, and volume of runoff for the two stations. Several additional flows occurred but were not recorded.

Rainfall-runoff events used to calibrate the basin models

| Date | Rainfall (in.) | Peak ($ft^3/s$) | Runoff (in.) | Runoff (acre-ft) |
|---|---|---|---|---|
| North Divide Draw near Recluse, Wyoming | | | | |
| 07-03-76 | 0.44 | 26.0 | 0.032 | 2.97 |
| 07-11-76 | 0.41 | 32.0 | 0.041 | 3.72 |
| 07-13-76 | 0.55 | 93.0 | 0.078 | 7.13 |
| 07-21-76 | 0.31 | 10.0 | 0.027 | 2.48 |
| 07-27-76 | 1.07 | 153.0 | 0.121 | 11.10 |
| 09-15-76 | 0.20 | 9.1 | 0.016 | 1.45 |
| 06-11-77 | 0.43 | 8.1 | 0.015 | 1.39 |
| 06-12-77 | 0.40 | 16.0 | 0.027 | 2.51 |
| 06-12-77 | 0.80 | 272.0 | 0.177 | 16.20 |
| 07-11-77 | 0.21 | 12.0 | 0.013 | 1.20 |
| Elk Creek Tributary near Recluse, Wyoming | | | | |
| 07-11-76 | 0.41 | 5.2 | 0.006 | 0.70 |
| 07-13-76 | 0.55 | 7.8 | 0.013 | 1.45 |
| 07-21-76 | 0.21 | 3.7 | 0.002 | 0.24 |
| 07-26-76 | 1.20 | 55.0 | 0.045 | 5.00 |
| 06-12-77 | 1.06 | 282.0 | 0.103 | 11.6 |
| 08-08-77 | 0.15 | 1.5 | 0.001 | 0.06 |

Starting model parameter values were obtained by using an average value for each parameter from 22 small basins studied by Craig and Rankl (1978). Six parameters were optimized to obtain a model fit for the two basins: PSP, KSAT, DRN, RGF, BMSM, and RR. The evaporation-pan coefficient (EVC) and the parameters that represent variation of infiltration with the time of the year (CKMN, CKMX, and CKEX) were held constant and not optimized. The routing parameters of the model were fitted by holding the optimized excess-runoff parameters constant and optimizing the routing parameters (KSW, TC, TP). This resulted in a skewed fit of the peak events. The skew was removed by using trial and error values of the storage coefficient (KSW) and optimizing the time-area histogram parameters (TC, TP). Model parameters and values for the two basins are listed in Table 35. These parameter values were used in conjunction with long-term weather records to generate the annual runoff volumes and peaks.

## Long-Term Weather Records

Long-term precipitation records were obtained from the National Weather Service for the station located at Cheyenne, Wyoming. The period of record was from April 1, 1901, to September 30, 1973, providing 73 years of data. Pan-evaporation data were obtained for 1913-73 from the Archer Field Station located about nine miles east of Cheyenne. The Cheyenne precipitation record and the Archer Field Station record are the longest continuous record available in Wyoming and are similar to rainfall patterns and evaporation conditions in the Recluse area (Craig and Rankl, 1978). Precipitation and evaporation data must be for the same period of record; therefore, the evaporation data were extended back to 1901 by relating evaporation to seasonal precipitation. Weather data could have been obtained for the 1974-77 period, but in this report a comparison of runoff characteristics from the two modeled basins is made with results from a regional study based only on the 1901-73 record.

The rate of infiltration for a given storm is partly controlled by the soil moisture at the beginning of the storm. Therefore, it is important that the amount of daily rainfall and evaporation at the long-term station represents climatic conditions at or near the study sites. This is accomplished by adjusting the long-term daily precipitation and evaporation data by a correction factor. The correction factor for daily precipitation is a ratio of the mean-annual (MA) precipitation (ppt) at a nearby short-term station and the mean-annual precipitation at the long-term station.

$$\text{Daily precipitation correction factor} = \frac{\text{MA ppt Recluse} = 13.59 \text{ in.}}{\text{MA ppt Cheyenne} = 15.06 \text{ in.}} = 0.90$$

The correction factor for daily evaporation (evap) was computed in the same manner as daily precipitation.

$$\text{Daily evaporation factor} = \frac{\text{MA evap Gillette 2E} = 43.75 \text{ in.}}{\text{MA evap Archer} = 41.54 \text{ in.}} = 1.05$$

Precipitation frequency of short-duration, high-intensity rainfall events was investigated to determine if the storms that produced the annual runoff were similar in duration to the storms used to calibrate the model. The 50-year, 6-hour storm event was selected for this comparison. Data for comparison was obtained from a precipitation-frequency atlas of the Western United States (Miller and others, 1973).

$$\text{Unit precipitation correction factor} = \frac{\text{50-year 6-hour storm Recluse 2.8 in.}}{\text{50-year 6-hour storm Cheyenne 2.6 in.}} = 1.08$$

The unit precipitation correction factor was applied to each 5-minute increment of each storm of the long-term record at Cheyenne, Wyoming.

A long-term simulation program was used to compute the maximum annual runoff and peak. This program used the parameters from the calibrated basin model and the adjusted long-term precipitation and evaporation records to generate the 73 years of data.

Table 35--Model parameters and values

| Parameter | North Divide Draw | Elk Creek tributary |
|---|---|---|
| PSP[1] | 4.45 | 31.78 |
| KSAT[1] | .087 | .173 |
| DRN[1] | .105 | .099 |
| RGF[1] | 11.99 | 44.36 |
| BMSM[1] | 3.95 | 1.01 |
| EVC[1] | .664 | .664 |
| RR[1] | .300 | 1.00 |
| CKMN | 1.53 | 1.53 |
| CKMX | 1.75 | 1.75 |
| CKEX | 27.5 | 27.5 |
| Volume objective function | .032 | .149 |
| KSW[1] | .620 | .399 |
| TC[1] | 7.37 | 8.30 |
| TP[1] | 5.08 | 6.14 |
| Peak Objective Function | .080 | .289 |

[1] Optimized parameters

A log-Pearson Type III cumulative probability distribution is assumed for the data samples of volumes and peaks (U.S. Water Resources Council, 1967). The first three moments of the distribution, mean of logarithms, standard deviations of logarithms, and coefficient of skewness are computed to estimate the statistics of the population. Peak discharges and runoff volumes are computed for selected recurrence intervals using the sample statistics. A frequency line is shown by plotting the runoff characteristic versus the recurrence interval. Plots of runoff in inches and peak discharge in cubic feet per second versus recurrence interval in years for North Divide Draw and Elk Creek tributary are shown in Figures 35 and 36.

## Comparison of Runoff from Basins

Runoff from North Divide Draw is five to eight times greater than runoff from Elk Creek Tributary and peak discharges are three to five times greater. Figures 35 and 36 show this comparison.

Infiltration, as used in the rainfall-runoff model, represents the total loss of precipitation from various hydrologic functions. These functions include depression storage, interception, channel loss, bank storage, and water uptake by the soil. Elk Creek tributary has a larger flat upland area with denser sage and more grass than North Divide Draw, which would result in greater depression storage and interception. Springs along the lower reaches of North Divide Draw keep the channel saturated, reducing channel loss and bank storage in the alluvium. The major differences in infiltration between the two basins are caused by differences in distribution of exposed clinker as shown in Figures 29 and 30. No evidence of flow was observed in the downstream tributary, which drains one-fifth of the basin, where it enters Elk Creek tributary above the gage.

The results obtained by applying basin characteristics in Table 34 to runoff equations by Craig and Rankl (1978, p. 27) were compared to the results of this study. Table 36 shows this comparison for peak discharge (Q) and volume (V) for selected recurrence intervals. Runoff characteristics, as defined by this study, were 19 to 33 percent higher for North Divide Draw and 80 to 88 percent lower for Elk Creek tributary than those obtained by applying basin characteristics to equations by Craig and Rankl (1978).

Confidence limits were constructed one standard error on each side of the centroidal point of the regression plane at selected recurrence intervals for the regional model (Figures 37 and 38). Runoff and peak-frequency curves for North Divide Draw and Elk Creek tributary were plotted on the same graphs to determine if data from these basins are of the same population used in the regional study. North Divide Draw data are within the confidence limits of the regional study. Greater runoff from nonclinker areas caused by higher storm intensities than those experienced in the regional study and decreased channel losses due to spring discharge may have compensated for the increased infiltration rates in areas of exposed clinker. Elk Creek tributary data are outside the confidence limits, and therefore are not of the same population.

## Quality of Water

### Chemical Quality

Adequate data for describing the chemical quality of surface water were not obtained during this study. The analyses of samples that were collected are included in Table 37, Appendix F.

## Impacts of Mining on Surface Water Hydrology

Effects of surface mining on surface water hydrology can be evaluated in two ways: (1) Compare results of hydrologic investigations based on data collected before and after mining, and (2) estimate changes in the hydrologic system from detailed mining and reclamation plans. Because data are not available for the above methods, investigations for this report are restricted to sensitivity evaluation of selected hydrologic functions of the study area.

The rainfall-runoff model of North Divide Draw basin provides a tool to evaluate the effects of infiltration on runoff. A 1-percent, a 2-percent, and a 3-percent increase and decrease in infiltration were six conditions that were assumed. The model calibrates on runoff by optimizing a set of parameters which controls the infiltration; therefore, a new set of runoff values for each event was computed. The following set of equations were used to compute the adjusted runoff values.

$$I = RF - RO \qquad (1)$$

$$I_a = I \times C \qquad (2)$$

$$RO_a = RF - I_a \qquad (3)$$

where:

$I$ = total infiltration of an event in inches.

$RF$ = total measured rainfall for an event in inches.

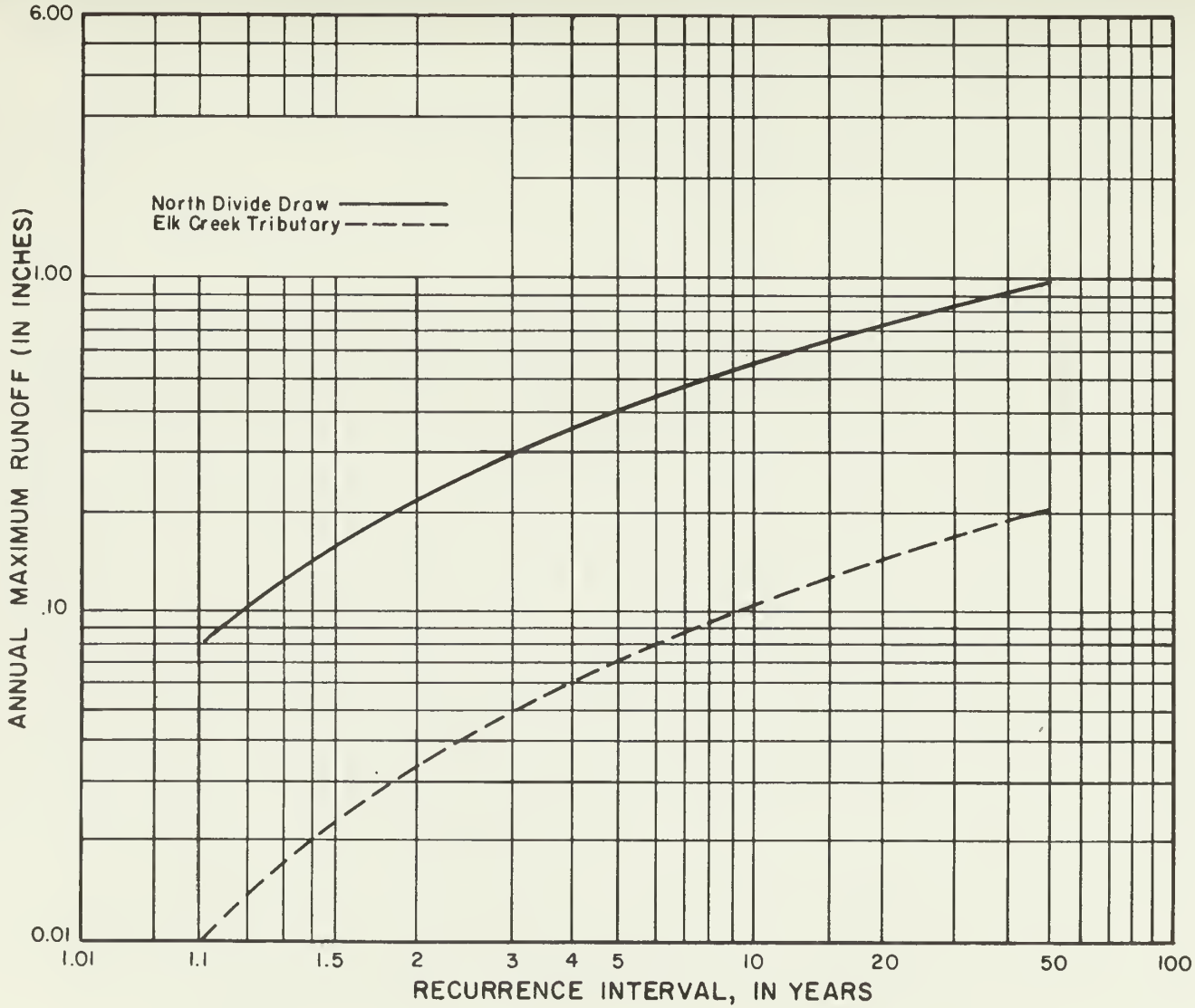
$RO$ = total measured runoff for an event in inches.

$C$ = assumed percent change in infiltration.

$I_a$ = adjusted infiltration in inches.

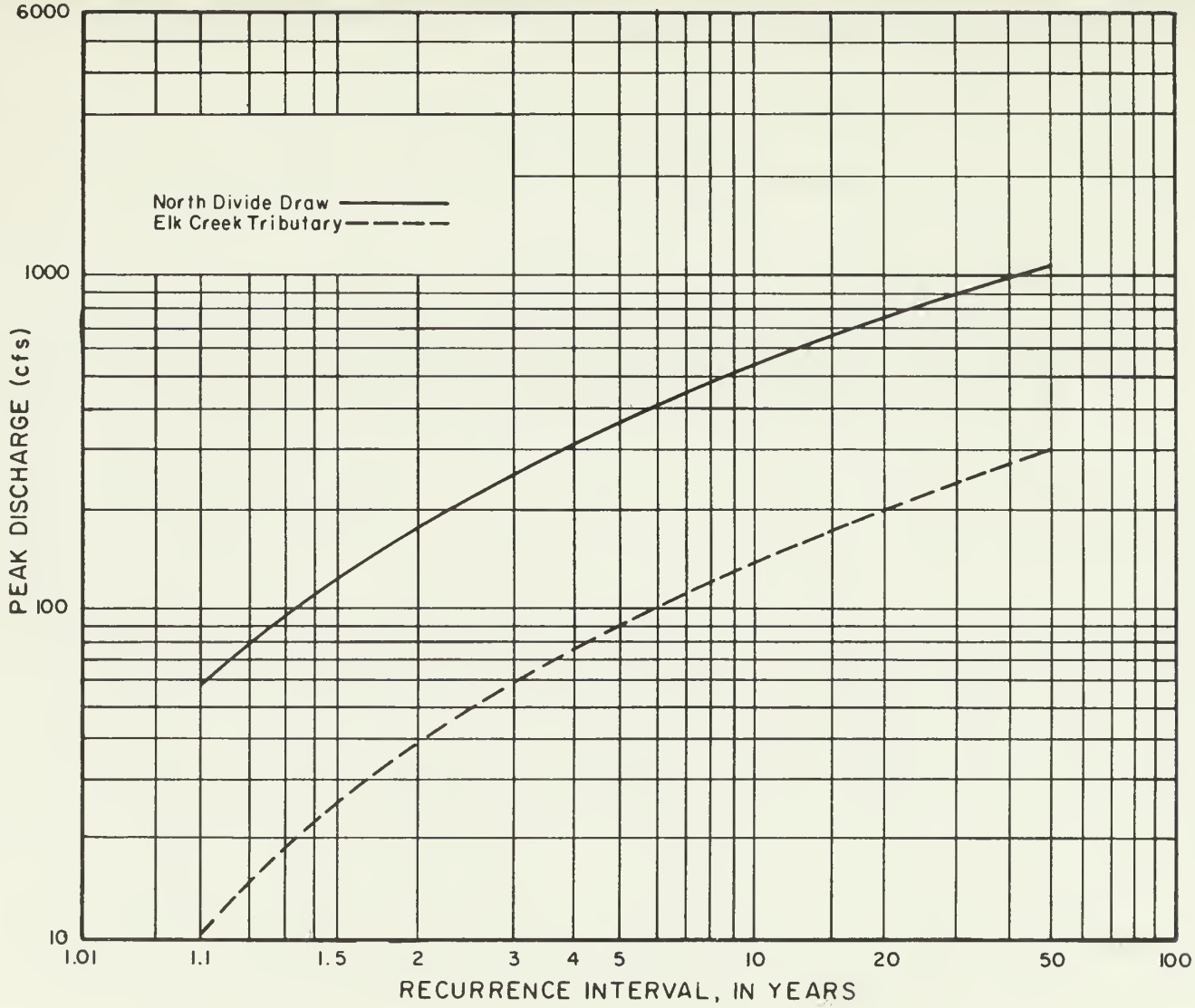
$RO_a$ = adjusted runoff value in inches.

A new set of basin model runoff parameters were optimized for the six assumed infiltration conditions. Analysis of the parameter values for suction at the wetted front (PSP) indicated a trend when plotted against percent change of infiltration. The parameter values for PSP were smoothed and held constant, and the remaining runoff parameters were optimized. This process was repeated for each runoff parameter used in the original basin calibration. The objective function of runoff events was used to detect deterioration in quality of the




LOG – Pearson Type III Annual Maximum Runoff – recurrence curves, North Divide Draw and Elk Creek tributary near Recluse, Wyoming, based on 73 years of simulated data.

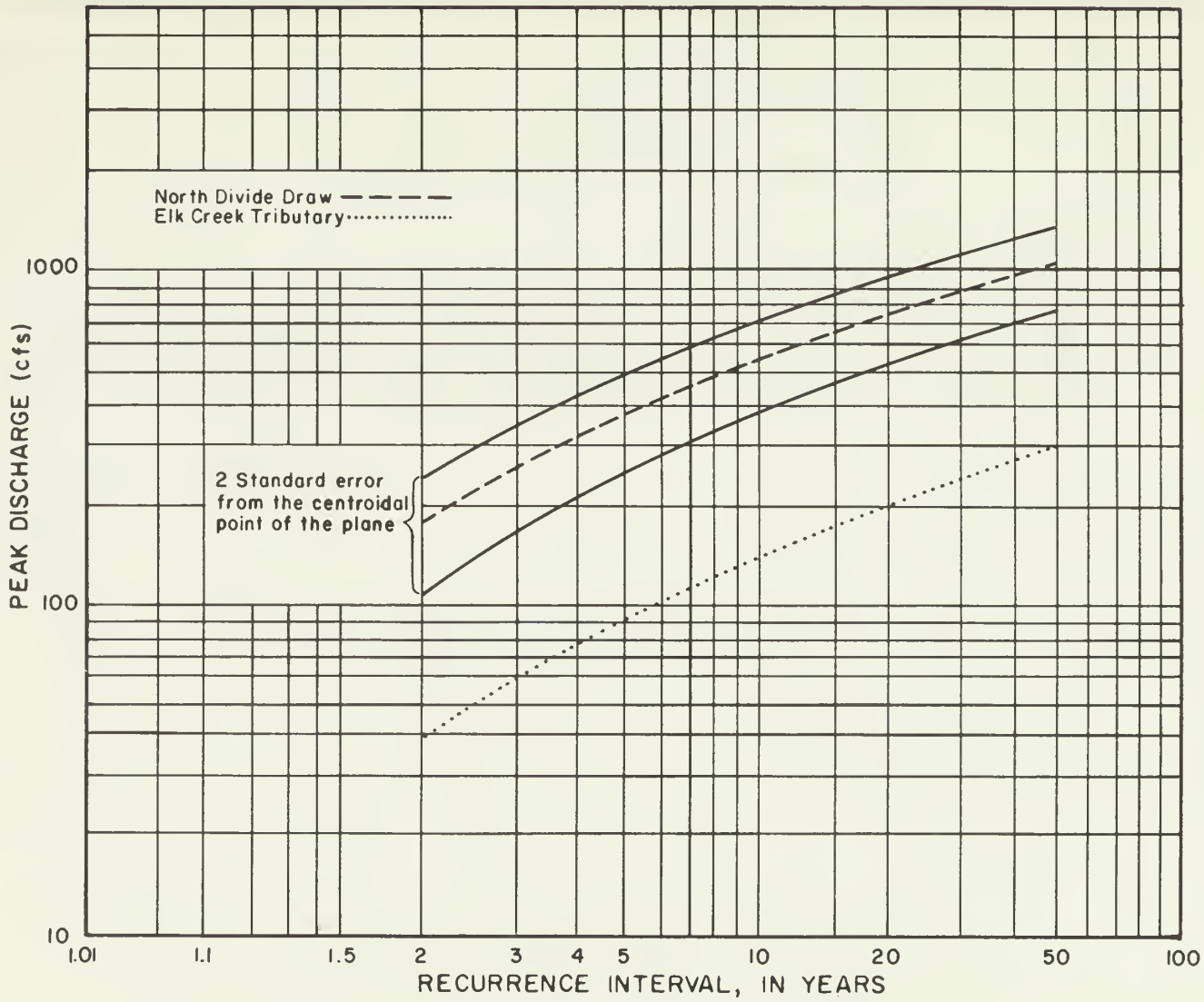
Figure 35




LOG - Pearson Type III - Peak Discharge, Recurrence Curves

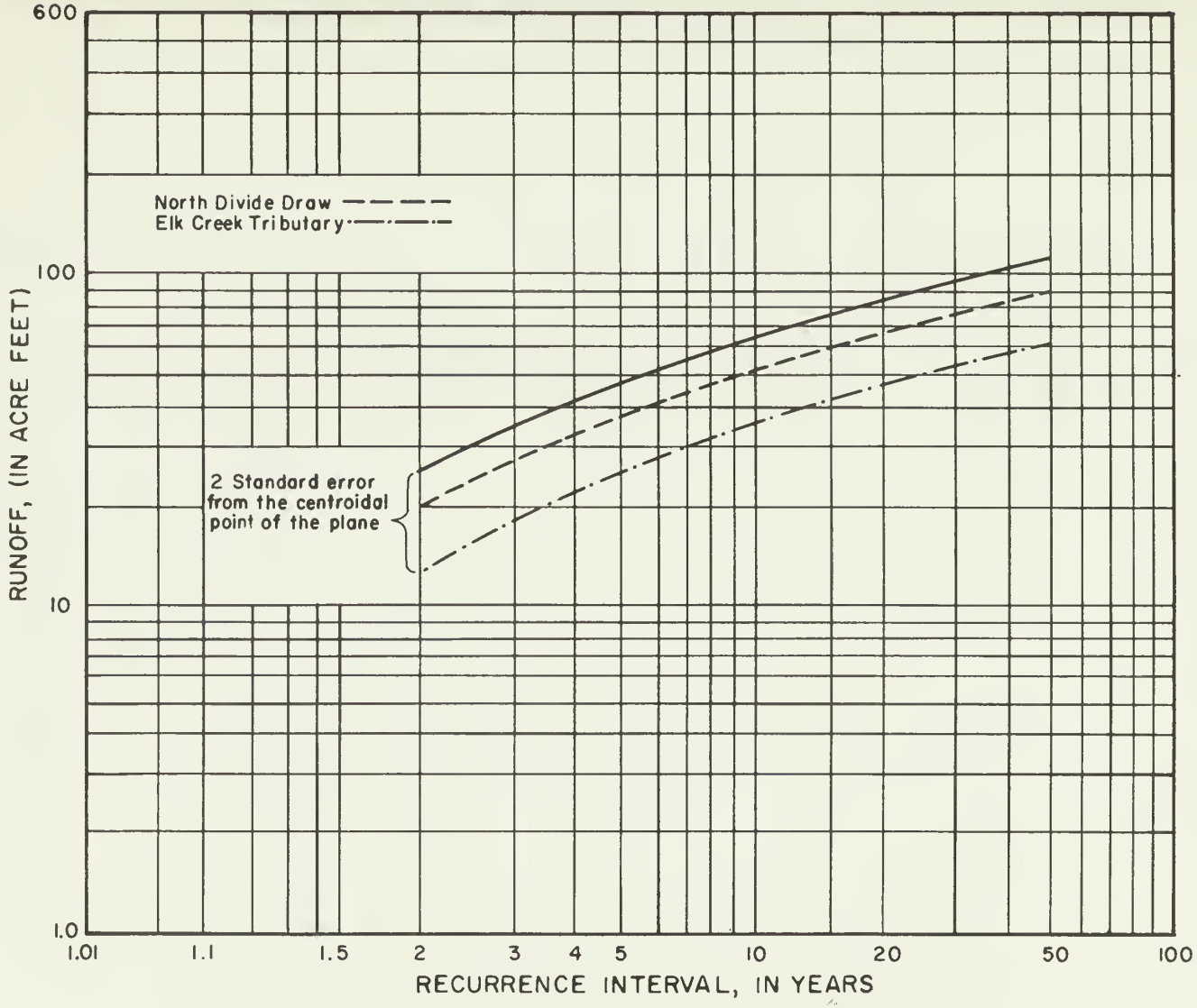
North Divide Draw and Elk Creek tributary near Recluse

Figure 36




Comparison of peak—flow samples with regional confidence limits.

Figure 37




Comparison of runoff-volume samples with regional confidence limits

Figure 38

Table 36

Comparison of runoff characteristics obtained from the basin characteristics and this study

| Recurrence Interval (Yrs.) | North Divide Draw: Basin characteristics ($ft^3/s$) | North Divide Draw: This study ($ft^3/s$) | North Divide Draw: Percent Differences | Elk Creek tributary: Basin characteristics ($ft^3/s$) | Elk Creek tributary: This study ($ft^3/s$) | Elk Creek tributary: Percent Difference |
|---|---|---|---|---|---|---|
| $Q^2$ | 146 | 178 | +0.22 | 315 | 39 | -0.88 |
| $Q^5$ | 306 | 368 | + .20 | 630 | 91 | - .86 |
| $Q^{10}$ | 451 | 540 | + .20 | 904 | 140 | - .85 |
| $Q^{25}$ | 684 | 816 | + .19 | 1324 | 222 | - .83 |
| $Q^{50}$ | 899 | 1066 | + .19 | 1712 | 298 | - .83 |
| (Yrs.) | (Acre-ft) | (Acre-ft) | | (Acre-ft) | (Acre-ft) | |
| $V^2$ | 15.22 | 20.00 | +0.31 | 30.89 | 3.70 | -0.88 |
| $V^5$ | 28.22 | 37.43 | + .33 | 53.36 | 8.06 | - .85 |
| $V^{10}$ | 38.81 | 51.46 | + .33 | 70.93 | 11.87 | - .83 |
| $V^{25}$ | 54.07 | 71.83 | + .33 | 96.32 | 17.58 | - .82 |
| $V^{50}$ | 67.17 | 88.71 | + .32 | 113.6 | 22.62 | - .80 |

fit, and each fit was plotted to check for skewness. Figures 39 through 44 are plots of parameter responses to the changes in total infiltration.

Overland flow parameters defined by the original basin calibration were used for all conditions of infiltration. Stress to the overland flow parameters could not be determined because it is related to basin or channel characteristics and to hydrograph shape.

The new set of optimized parameters from the adjusted runoff values were used in conjunction with the long-term records of runoff and peaks. Log-Pearson Type III distribution was applied to the adjusted record to determine a set of frequency distributions showing change in runoff with change in infiltration. Figures 45 and 46 show runoff and peak discharges for selected recurrence intervals for changes in infiltration for North Divide Draw. A 1-percent change in infiltration results in about a 10-percent change in runoff and peaks.

## Sediment Yields

The sediment yield values presented for this area were derived using a numerical rating method developed by the Pacific Southwest Inter-agency Committee (PSIAC) (1968). They have been judged to be reasonably accurate, but they have been only partially verified by field measurements.

The mapping unit that is the basis of this sediment yield evaluation is the source area which is defined as a small drainage area occurring on a single landform type or an inseparable complex of landforms and which is only part of a complete drainage basin. The PSIAC method is used to assess the hydrologic variation of the given landforms as well as to make estimates of sediment yield from them. Numerical ratings are assigned for each of the nine factors of the PSIAC method to representative sediment-source areas in accordance with the degree of influence each factor has on the sediment yield from the area. These nine factors are surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion and channel erosion, and sediment transport. The method was developed to make broad sediment yield classifications for large areas, such as river subbasins, but Shown (1970) found that the method provides reasonable estimates for small drainage basins (.02-7.5 sq mi). In applying the method on source areas, some adjustments are made because a complete drainage system is not being considered. Alluvial fan and flood plain development are not considered in the topography factor and sediment-transport capabilities are not considered for channels that originate in upslope source areas, and that cross through the source area being rated. These factors are taken into account later when making estimates of sediment discharge from drainage basins.

Interpretations of color aerial photographs (1:24,000 scale) were used to extend the source-area sediment-yield estimates to those areas that were not rated during field investigations. This was accomplished with a stereo plotter and resulted in the source-area sediment-yield map shown on Plate 36. The slope data were obtained from the 1:24,000 USGS topographic quadrangles. Bare soil data were extrapolated from measurements made at about 20 sites in the study area.

The complete main channel system was classified and mapped according to channel type and condition (Plate 37) to aid in assessing channel erosion and deposition. The channel classification was done by interpretation of the aerial photography and only those channels that were larger than third or fourth order according to Strahler's (1952) classification were delineated.

Sediment accumulation was measured in two stock-water ponds in the area by probing from a boat. The average annual rate of sediment accumulation in the ponds (see table on Plate 37) was divided by the area-weighted average source-area sediment yield to obtain sediment conveyance factors for the channels above the ponds. The sediment-conveyance factor represents that part of the total sediment load entering the main channel and principal tributaries that is transported on through the channel system and not deposited somewhere enroute. The computed sediment-conveyance factors were used as guides when applying the channel classification information on Plate 37 to obtain estimates of the sediment-conveyance factors for subbasins for which estimates of annual sediment discharges were made (see table in upper left corner of Plate 37). The method used in assigning sediment-conveyance factors was the one reported by Frickel, Shown, and Patton (1975).

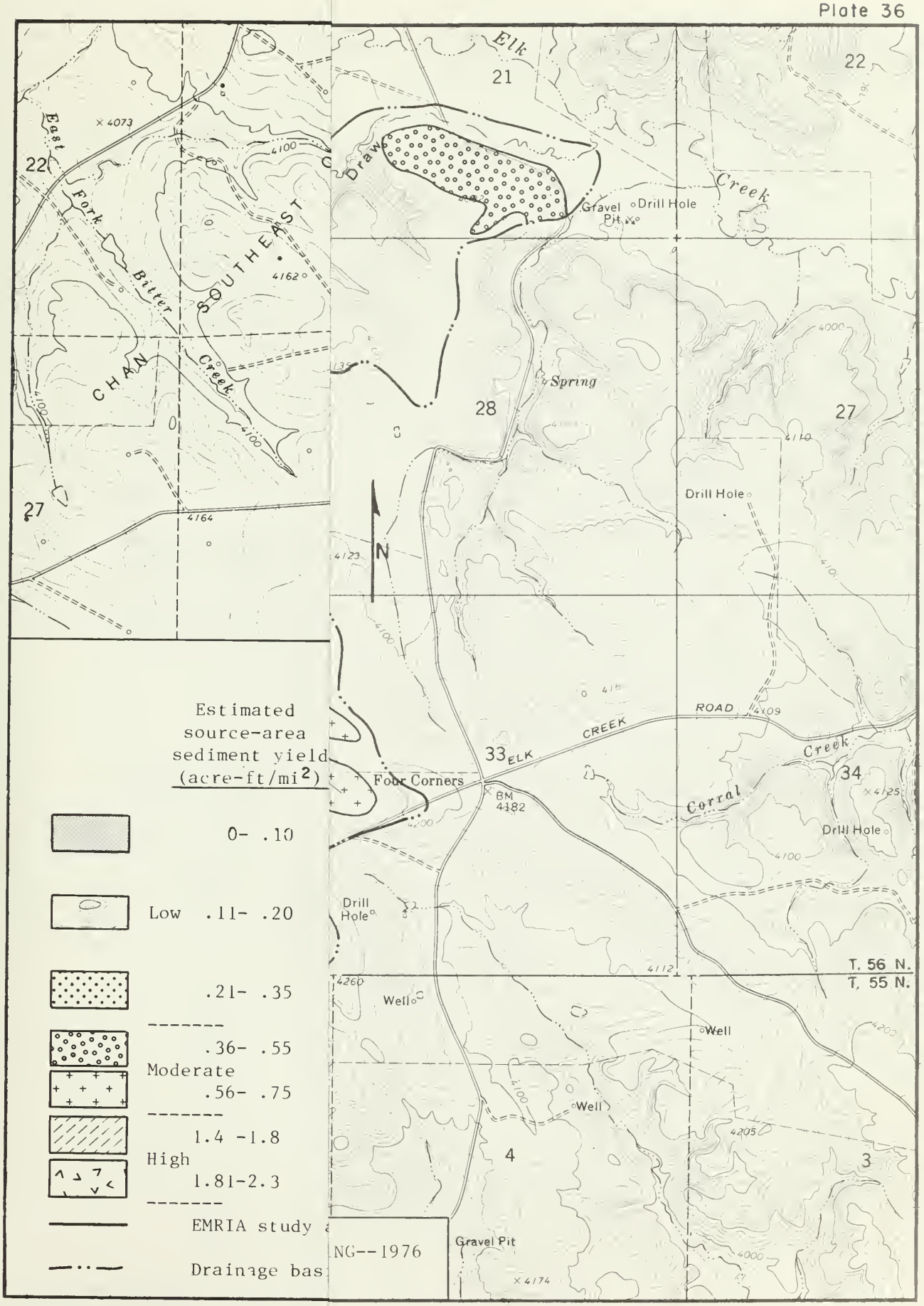
## Source-Area Sediment Yields

Sediment yields from source areas are rather variable in the area (Plate 36) in response to different types of surficial materials and the associated vegetation and relief. Lowest yields occur from bottomland alluvium, from clinker-mantled rolling plains and hillslopes, and from rolling plains and mesas underlain by sandstone, siltstone or old alluvium. Most of these areas have excellent vegetative cover and little bare soil (see explanation table on Plate 36). Highest sediment yields occur from steep, finely dissected hillslopes consisting of partially weathered siltstones, mudstones, and claystones. These hillslopes are characterized by much more bare soil than the low-yielding areas. Moderate sediment yields occur from hill-and-valley areas having a variety of surficial materials. In general, these areas have less bare soil and are much less dissected than the high-yielding areas.

Channel erosion is also a variable in the study area. A number of headcuts occur in the area, with the highest density of them occurring in the steep dissected areas (see Plate 37). Some of these headcuts appear to be actively advancing, but no data is available on the rates of advance.

## Sediment Discharge from Drainage Basins

Sediment accumulation was measured in two stock ponds. The computed annual rates of sediment accumulation shown in the lower right corner of Plate 37 reflect the differences in surficial materials, relief, and cover of the two basins above the ponds. Much of the basin above pond E consists of steep, dissected hillslopes that yield high quantities of sediment, and sediment is efficiently conveyed by the channels to the pond. Much of the basin above the other pond is mantled with clinker. Therefore, runoff and erosion is much lower on that watershed and sediment transport is less efficient as the main channel beds appear to be aggrading. These factors account for the


Estimated source-area sediment yield (acre-ft/mi²)
0- .10
Low .11- .20
.21- .35
.36- .55
Moderate .56- .75
1.4 -1.8
High 1.81-2.3
EMRIA study a
Drainage bas
NG--1976
Elk
Draw
Creek
East Fork Bitter Creek
CHAN SOUTHEAST
Gravel Pit
Drill Hole
Spring
Drill Hole
Four Corners
BM 4182
ELK CREEK ROAD
Corral Creek
Drill Hole
Drill Hole
Well
Well
Well
Gravel Pit
T. 56 N.
T. 55 N.
21
22
22
27
27
28
33
34
4
3
N

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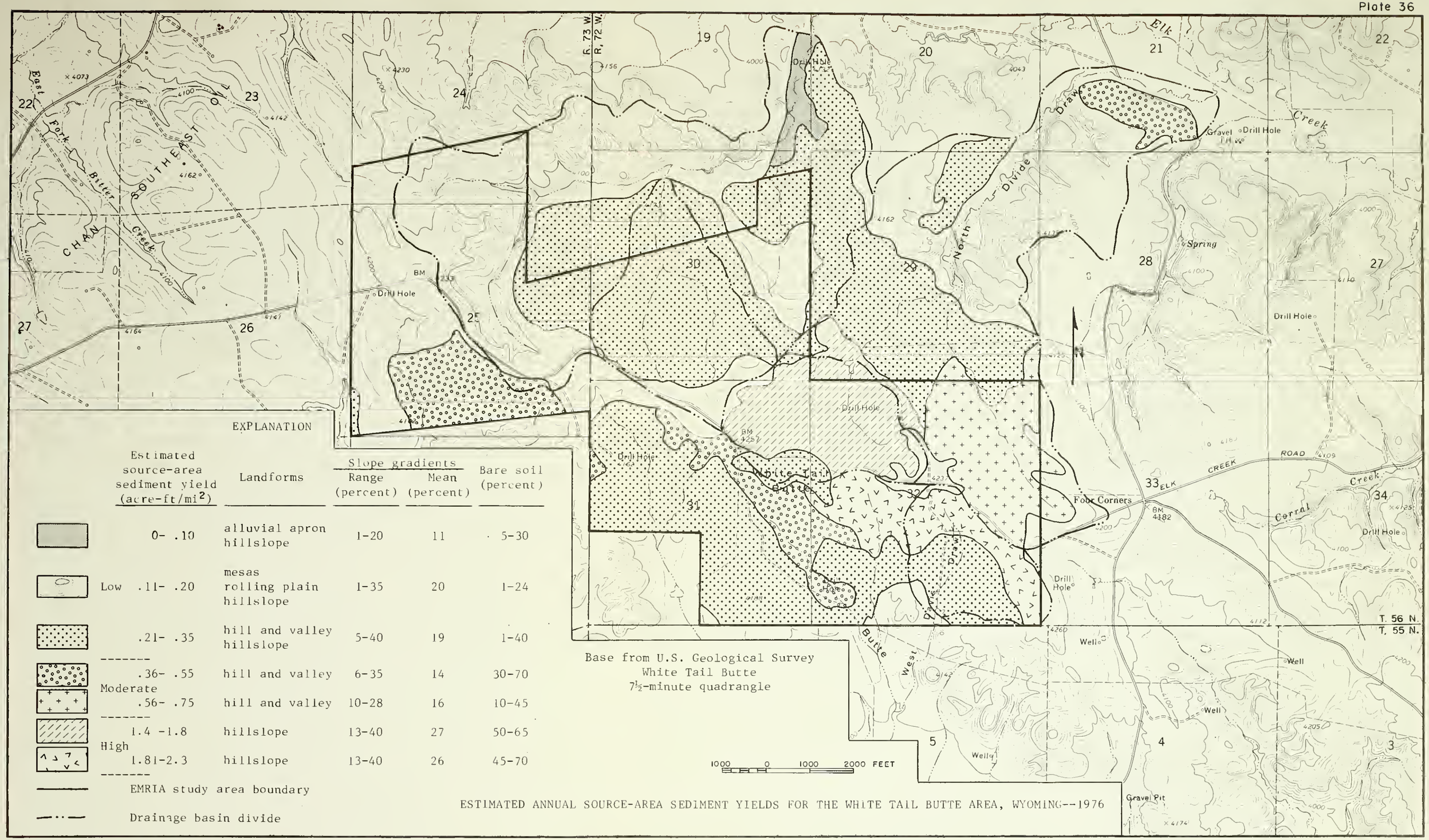



EXPLANATION

| | Estimated source-area sediment yield (acre-ft/mi²) | Landforms | Slope gradients Range (percent) | Slope gradients Mean (percent) | Bare soil (percent) |
|---|---|---|---|---|---|
| | 0- .10 | alluvial apron hillslope | 1-20 | 11 | 5-30 |
| Low | .11- .20 | mesas rolling plain hillslope | 1-35 | 20 | 1-24 |
| | .21- .35 | hill and valley hillslope | 5-40 | 19 | 1-40 |
| Moderate | .36- .55 | hill and valley | 6-35 | 14 | 30-70 |
| | .56- .75 | hill and valley | 10-28 | 16 | 10-45 |
| High | 1.4 -1.8 | hillslope | 13-40 | 27 | 50-65 |
| | 1.81-2.3 | hillslope | 13-40 | 26 | 45-70 |

EMRIA study area boundary

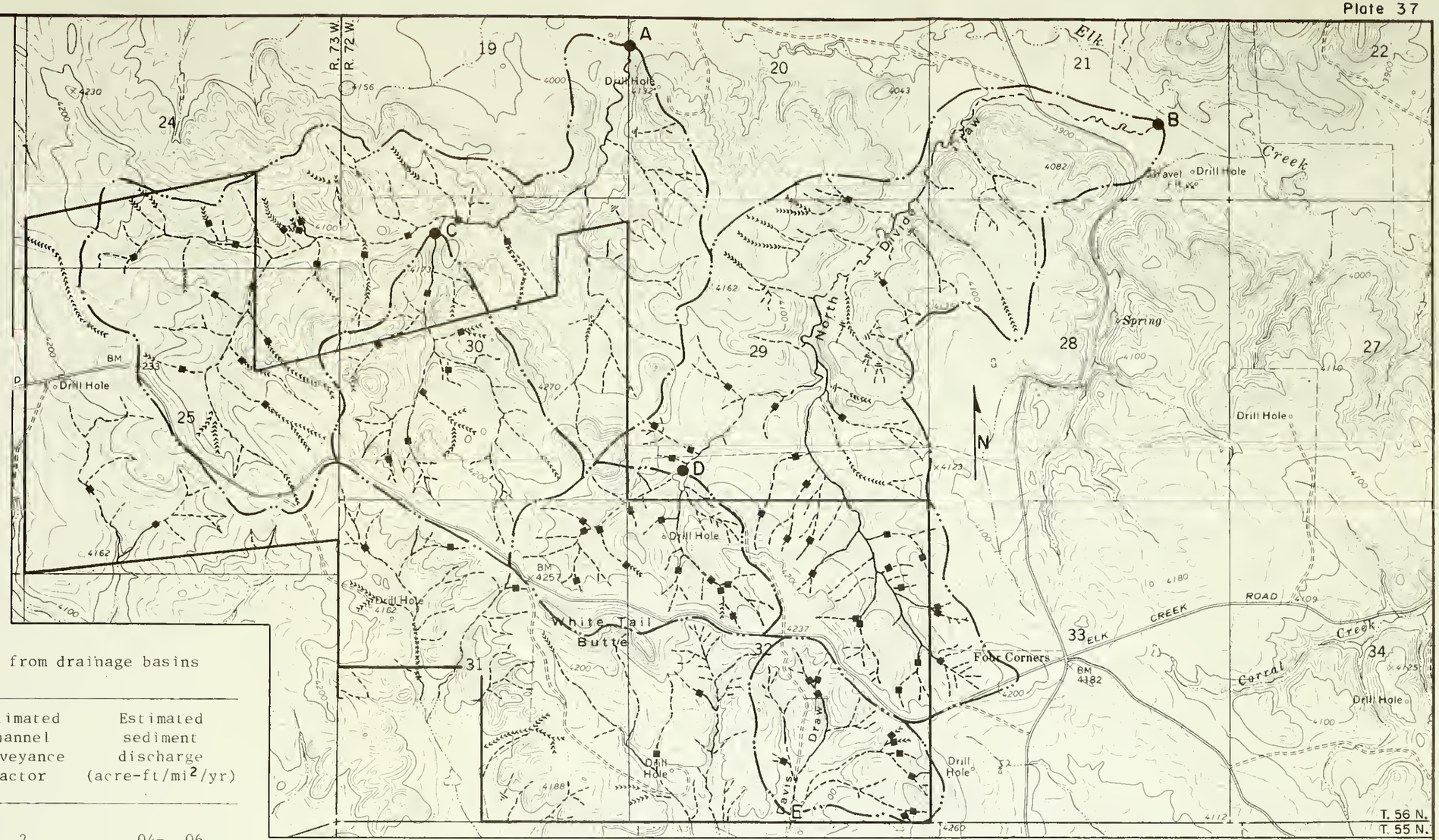
Drainage basin divide

Base from U.S. Geological Survey
White Tail Butte
7½-minute quadrangle

ESTIMATED ANNUAL SOURCE-AREA SEDIMENT YIELDS FOR THE WHITE TAIL BUTTE AREA, WYOMING--1976

EXPLANATION

- EMRIA study-area boundary
- Drainage basin divide
- Raw gully
- Gully with healed bed
- Untrenched channel
- Braided channel
- Alluvial fan
- Headcut
- Dam
- ●A Location where an estimate of annual sediment discharge was made
- E Stock pond where sediment accumulation was measured




Base from U.S. Geological Survey
White Tail Butte
7½-minute quadrangle

1000 0 1000 2000 FEET

Estimated annual sediment discharge from drainage basins

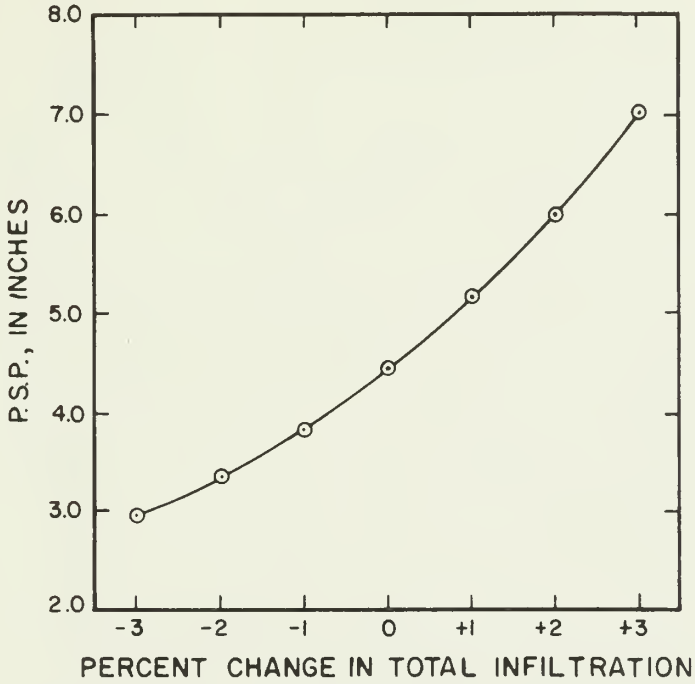
| Basin | Drainage ($mi^2$) | Weighted source-area sediment yield ($acre\text{-}ft/mi^2/yr$) | Estimated channel conveyance factor | Estimated sediment discharge ($acre\text{-}ft/mi^2/yr$) |
|---|---|---|---|---|
| A | 2.13 | .2 - .3 | .2 | .04- .06 |
| B | 1.99 | .4 - .55 | .15 | .06- .08 |
| C | .47 | .25- .35 | .45 | .11- .16 |
| D | .38 | 1.4 -1.7 | .9 | 1.26-1.53 |

Sediment accumulation in stock ponds

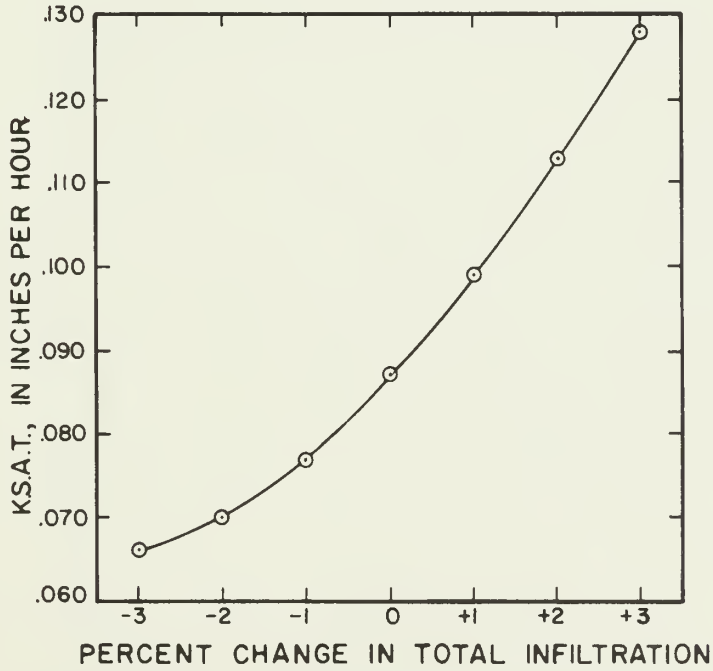
| Pond | Age (yrs) | Drainage area ($mi^2$) | Sediment accumulation | |
|---|---|---|---|---|
| | | | (acre-ft) | ($acre\text{-}ft/mi^2/yr$) |
| E | 8 | .28 | 2.89 | 1.32 |
| F[1] | 15 | .90 | 1.44 | .11 |

[1]Located in SE¼, NW¼, sec. 8, T. 55 N., R. 72 W.

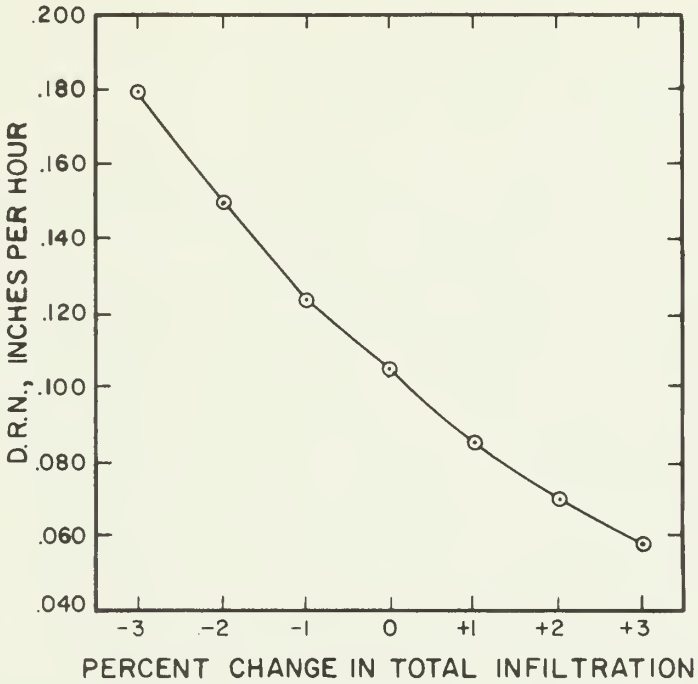
CHANNEL CLASSIFICATION AND ESTIMATES OF SEDIMENT DISCHARGE IN THE WHITE TAIL BUTTE AREA, WYOMING--1976



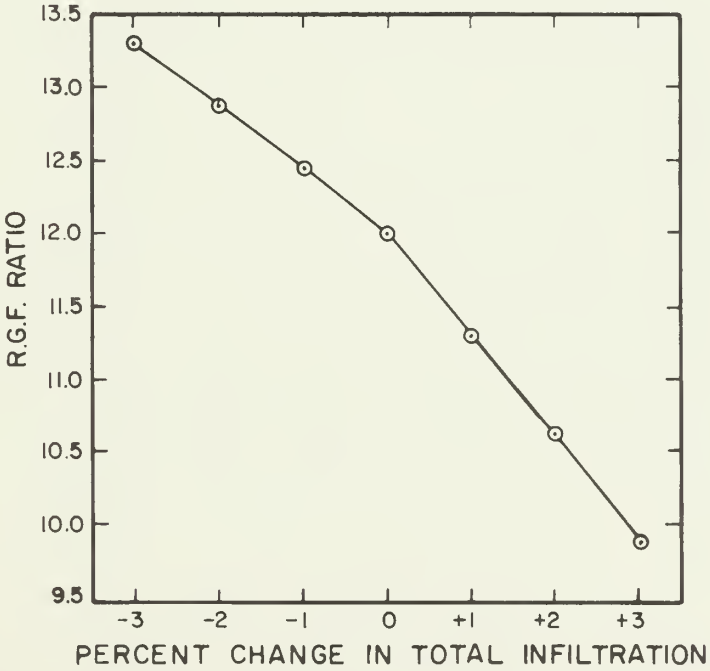

Change in P.S.P. for change in total infiltration



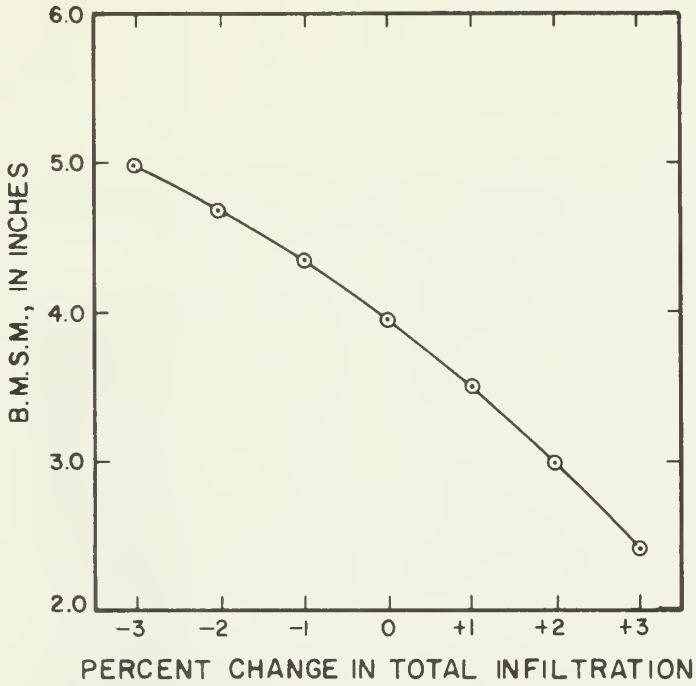

Change in K.S.A.T. for change in total infiltration



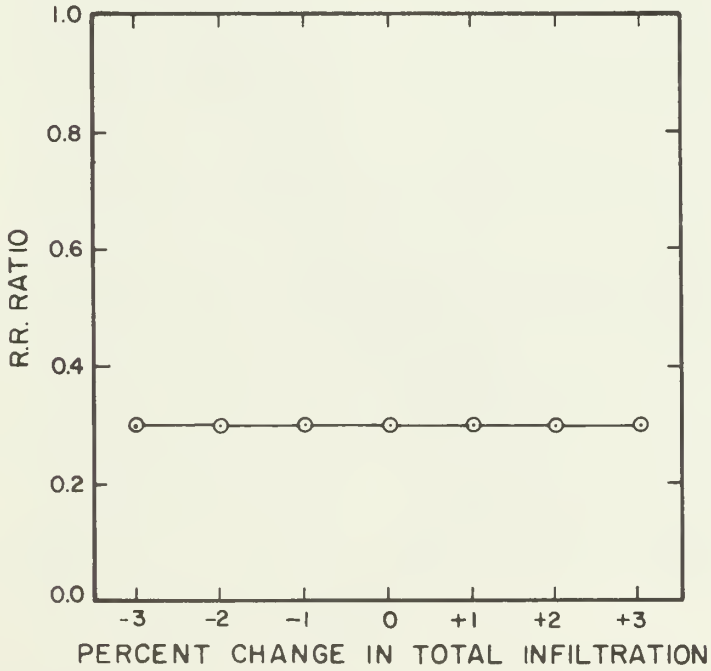

Change in D.R.N. for change in total infiltration



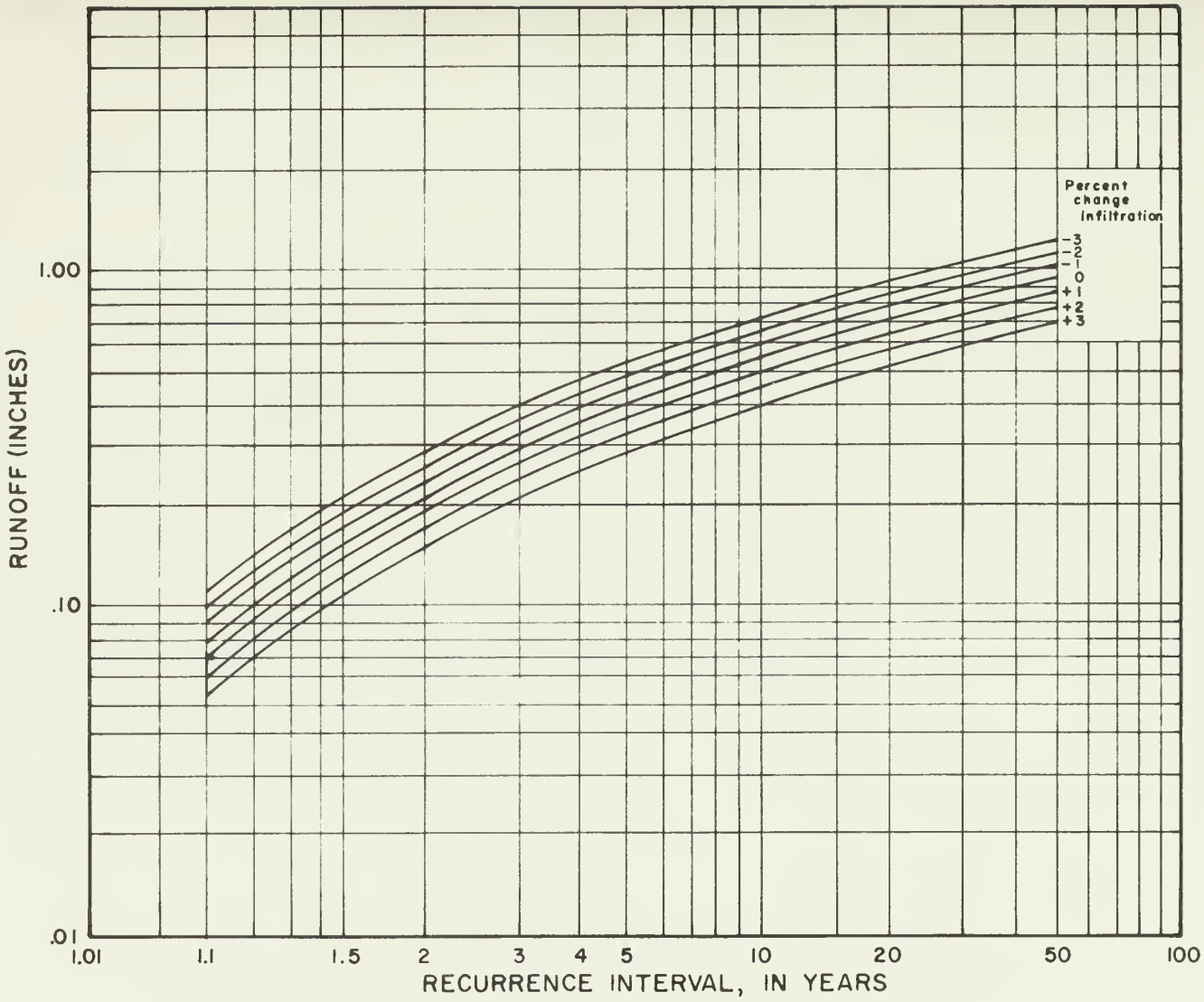

Change in R.F.G. for change in total infiltration




Change in B.M.S.M. for change in total infiltration

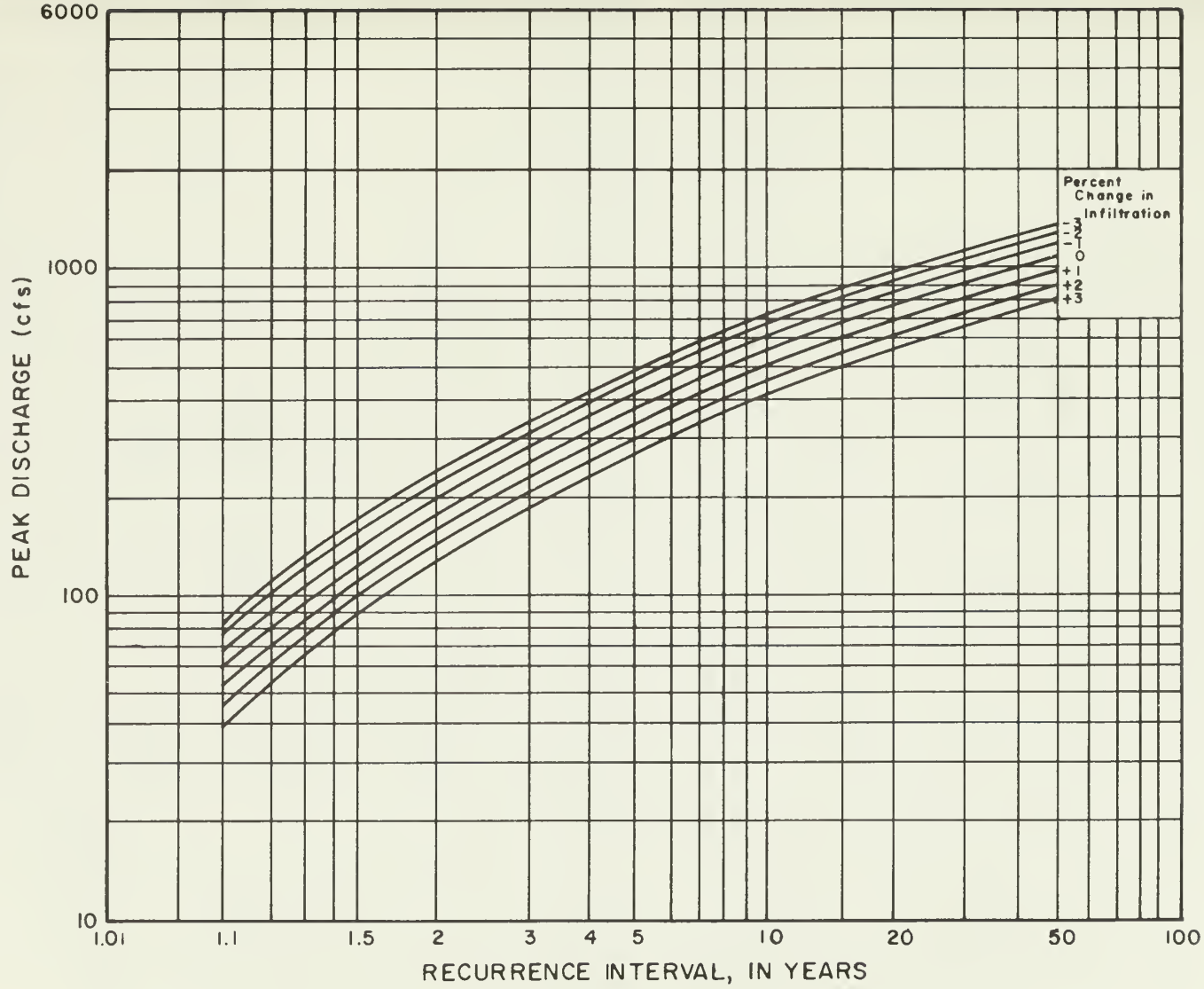



Change in R.R. for change in total infiltration




RUNOFF—Frequency curves adjusted for infiltration

Figure 45




PEAK DISCHARGE—Frequency curves adjusted for infiltration

Figure 46

much lower sediment yield from the basin in section 8, T. 55 N., R. 72 W., as compared to the basin above pond E. Variations in estimates of sediment discharge from other basins in the study area, shown in the lower left corner of Plate 37, are largely due to these same factors, which are largely controlled by types of surficial materials and basin relief.

The stock pond at the mouth of the basin D (Plate 37) was completely filled with sediment in September 1976 and a headcut had advanced to the lip of the spillway. This headcut will likely advance across and trench the sediment body, but erosion at that location should become minimal after that occurs. The capacity of pond E had decreased until there was only about 1.5 feet between the top of the sediment body and the lip of the spillway in September 1976. The trap efficiency of that pond, therefore, would be something less than 100 percent, so the sediment accumulation rate of 1.32 acre-ft/mi$^2$/yr (Plate 37) is somewhat less than the actual sediment yield from the basin above the pond.

## Computation of Annual Sediment Transport

Computations of the annual transport of sediment require a defined discharge-concentration rating curve, water temperature, and samples for both the rising and falling limb of the hydrograph. Automatic sediment samplers and accessible sites are needed to collect sufficient data to compute the sediment discharge for ephemeral streams which have flashy peak flows.

A qualitative analysis of sediment load cannot be made for North Divide Draw and Elk Creek tributary because of a lack of the required data. The following table lists the sediment samples collected during the study to show the concentrations sampled.

Sediment Samples Collected From

North Divide Draw and Elk Creek Tributary

by Single-Stage-Sediment Samplers

| Site | Date | Sampler Stage | Discharge (ft$^3$/s) | Concentration (mg/L) | Remarks |
|---|---|---|---|---|---|
| North Divide Draw | 4-16-77 | 0.81 | 52 | 6,050 | |
| | 5-18-77 | .81 | 26 | 8,360 | |
| | 6-10-77 | .81 | 8.1 | 79,900 | Possible enrichment by event of 6-12-77 |
| | 6-12-77 | 2.12 | 272 | 36,300 | |
| | 7-11-77 | .81 | 12 | 19,600 | |
| Elk Creek Tributary | 6-12-77 | .76 | 282 | 38,400 | |
| | 6-12-77 | 2.04 | 282 | 50,600 | |

## Ground-Water Hydrology

### Occurrence and Availability

Ground water in adequate quantities for stock and domestic use occurs in sandstone, coal, clinker, and alluvium. Seeps are sometimes associated with small landslides but may be antecedent to, and partly responsible for, the slides.

Clinker is the most permeable aquifer in the area but occurs only near the surface, and saturated thickness necessary for development by wells does not commonly occur. Well 55N 072W 03BB 01 is completed in clinker; however, springs produce most of the water from the aquifer.

No aquifer tests were conducted in the area in alluvial deposits. Similar deposits elsewhere have transmissivities as high as 160 $ft^2$/day, and this is probably the maximum that could be expected in the area.

Transmissivities of sandstone aquifers 1,000 feet deep or less range elsewhere in eastern Campbell County from about 50 to 1,200 $ft^2$/day, and the transmissivity of coal ranges from less than 1 to about 10,000 $ft^2$/day. Most transmissivity data is for the Wyodak coal which is equivalent to the combined Anderson and Canyon coal of the White Tail Butte area.

Deep sandstone aquifers have a low transmissivity, possibly because of compaction with depth. A well tested in eastern Campbell County that is perforated in the lower part of the Lance Formation and the Fox Hills Sandstone has a transmissivity of only 45 $ft^2$/day.

Depth of wells and water levels representative of those in the White Tail Butte area are given in Table 31, Appendix F. The location of the wells, springs, and testholes are shown in Figure 47.

### Quality of Water

The chemical quality of ground water in the area is a function of the solubility of minerals that the water initially contacts in the recharge area and the exchange reactions and additional solution as the water moves through the aquifer. Clinker, which is relatively insoluble and porous, underlies large areas. Precipitation falling on these clinker areas picks up relatively small amounts of dissolved solids, and the water moving through the clinker is a calcium-bicarbonate type. (See analysis for spring 56N 072W 21CCC01 in Table 38, Appendix F). The dominant lithologies are sandstone, shale, and coal which contain greater amounts of easily dissolved minerals than does clinker. The water in these rocks in recharge areas is a calcium-sulfate or calcium-magnesium-sulfate type, often with dissolved solids of 2,000 mg/L or more. Water moving through the aquifers undergoes cation exchange softening whereby sodium in the rocks is exchanged for calcium and magnesium in the water, and sulfate reduction whereby sulfate is reduced to form hydrogen sulfide with bicarbonate as a by-product. This results in water distant from the recharge being a sodium-bicarbonate type with dissolved solids of about 1,000 mg/L.

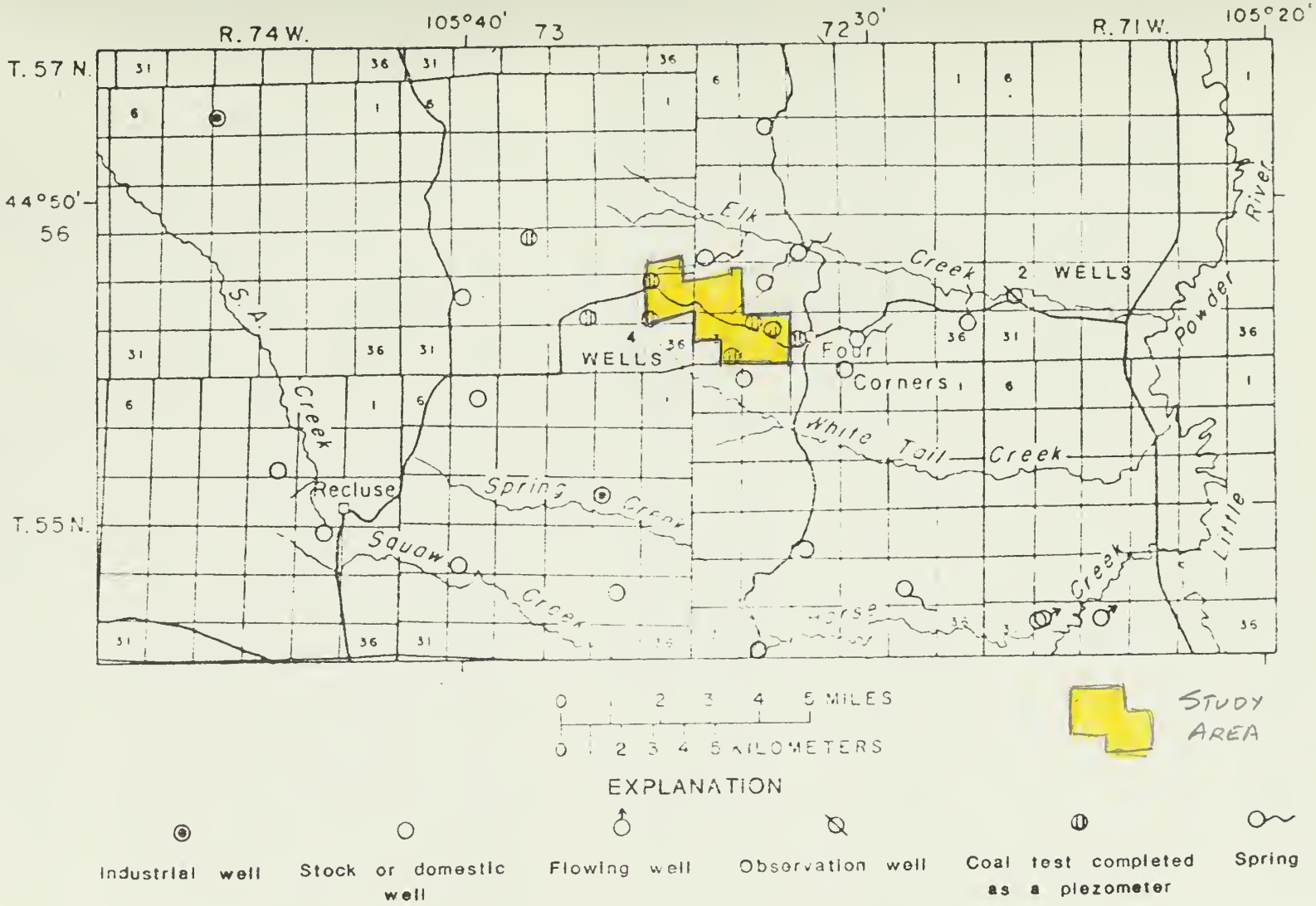



Figure 47 . Locations of wells, springs, and test holes listed in Table 31, Appendix F.

Figure 47

Riffenburg (1975) has described the chemical character of these waters in the northern Great Plains. The trilinear graph (Figure 48) shows that cation exchange occurs so that there is definite distinction between the calcium and sodium types. The reduction of sulfate is more transitional.

Piezometers in the Canyon Coal illustrate the relationship expected from flow through the regional system and that resulting from local recharge. Graphs show that water levels in three of four piezometers completed in the Canyon Coal (Figure 49) have little fluctuation, indicating the wells are far enough from the recharge area that fluctuation in water levels caused by variation in recharge is damped. The water from the wells is a sodium-bicarbonate type (Table 35) which also indicates recharge is distant from the wells.

more than 20 feet = almost 30'

The graph of the fourth well (56N 073W 25BBA01), however, does show a water-level fluctuation of almost 20 feet. This is attributed to natural conditions, because there are no producing wells in the area. Water from this well is a sodium-sulfate type, indicating that the distance the water has traveled in the aquifer was sufficient for ion exchange but not sufficient for sulfate reduction to be complete.

Although trace elements are found in coal and other minerals, only minor amounts are dissolved in the water (See Table 31,Appendix F.). Sulfate reduction is one mechanism limiting the trace elements, as metal sulfides are relatively insoluble at the pH of water in the area. The pH is maintained because, with cation exchange softening, the water is undersaturated with respect to calcium carbonate and further solution of the mineral increases the pH.

## Movement

Because of the topographic relief, there is an upper and a lower groundwater system in the area, separated by the Lebo Shale. The regional movement of water in the deeper aquifers is northward as shown in Figure 50. Although not all wells used in the figure are completed in the same stratigraphic zone, completion in at least the lower Lance and/or the Fox Hills is common. The northward movement is also indicated by a decreasing head with depth in the central part of Campbell County and an increasing head with depth in the northern part of the county. Figure 50 is in agreement with a map of the potentiometric surface in the Fox Hills-basal Hell Creek (Lance Formation) aquifer in Montana (W. R. Miller, oral commun., 1978). Preliminary studies indicate that within the Tullock and older aquifers the change from decreasing to increasing head with depth occurs along the Little Powder River at about the latitude of Weston. Wells 55N 071W 32BD 01 and 55N 071W 32BAD 01 are flowing wells completed in the Tullock (Table 31, Appendix F) and flow as might be expected from the regional relationship.

Data to form a conceptual model for flow in zones overlying the Lebo Shale are available only for the Wyodak Coal. Figure 51 shows the potentiometric surface in the Wyodak, compiled principally from data collected by mining

interests, and shows water levels when only the Wyodak Mine east of Gillette was operating. The map shows that although there is a very flat gradient in the southern part of Campbell County, recharge apparently occurs at the outcrop of the coal as far north as T. 46 N., and that the coal outcrop north of T. 49 N. is a discharge point.

The White Tail Butte Area is also a discharge point for the coalbed equivalents to the Wyodak and other beds above the Lebo Shale because the potentiometric surface in piezometers is generally higher than nearby outcrops of the stratigraphic zones in which the piezometers are completed.

The decreasing head with depth that occurs in aquifers overlying the Lebo Shale is consistent with a discharge area, where the head differences are the result of the poor vertical permeability caused by the large amount of shale in the section and different base levels to which the different zones discharge along the escarpment bordering the Little Powder River.

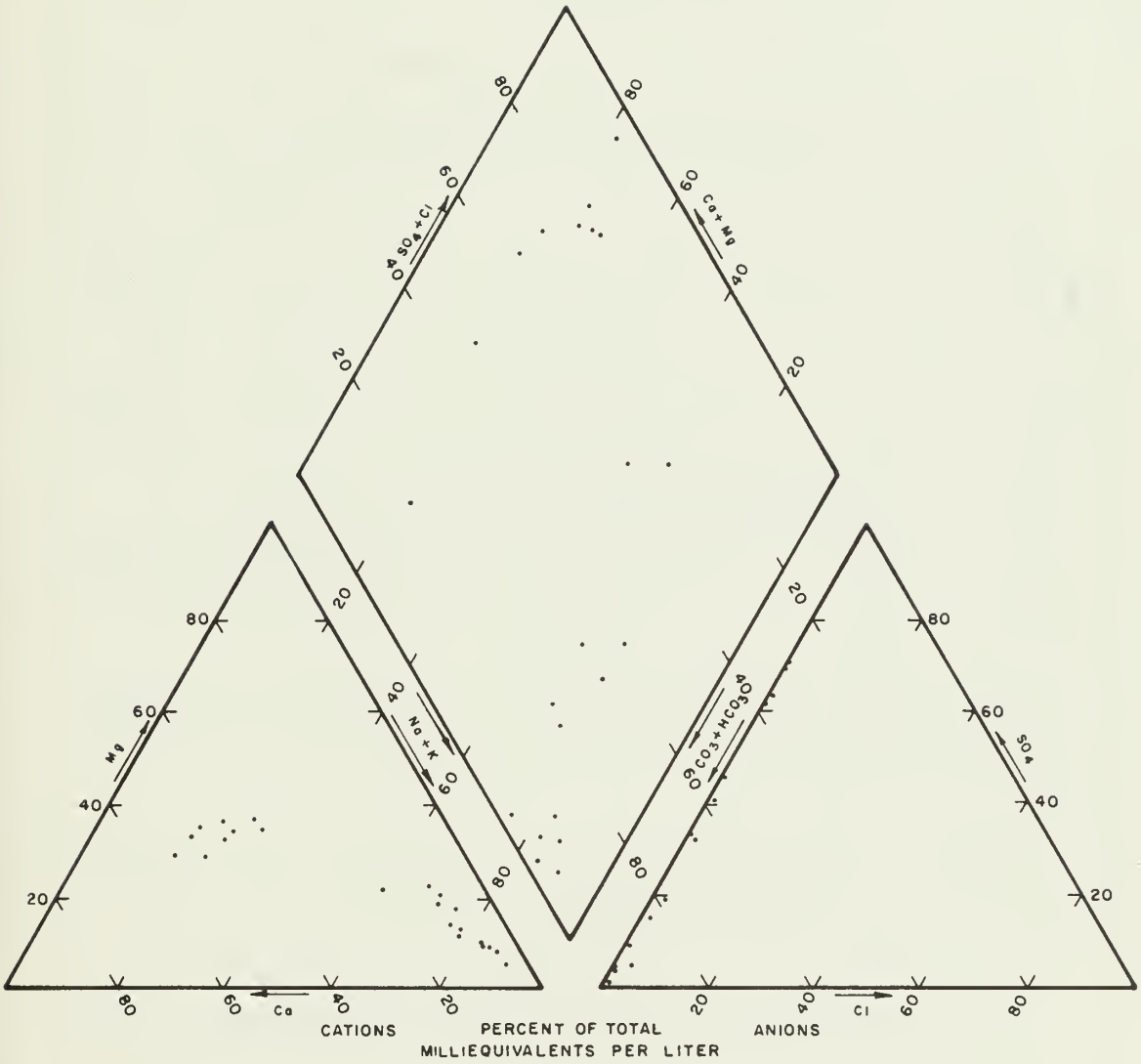
Figure 52 shows the relationship between water levels in piezometers finished in the Canyon Coal and the outcrop of the coal. The water levels are the lowest measured. Water levels in some wells in the area are known to be affected by the discharge of coal gas; however, preliminary results of studies in the area to determine the effect of gas on water levels show it is not significant.

Vertical movement may not be the major source of recharge to the regional flow in the Wyodak and equivalent coals a short distance basinward of the outcrop in southern Campbell County. However, if horizontal flow predominates where the beds are relatively deep, the amount of water moving through this part of the system must be small relative to that in the outcrop where local recharge occurs. Water samples collected from natural discharge points and from the alluvium in the White Tail Butte Area were of chemical types that occur near recharge areas rather than the sodium-bicarbonate type that occurs distant from recharge areas.

## Impacts of Mining on Ground-Water Hydrology

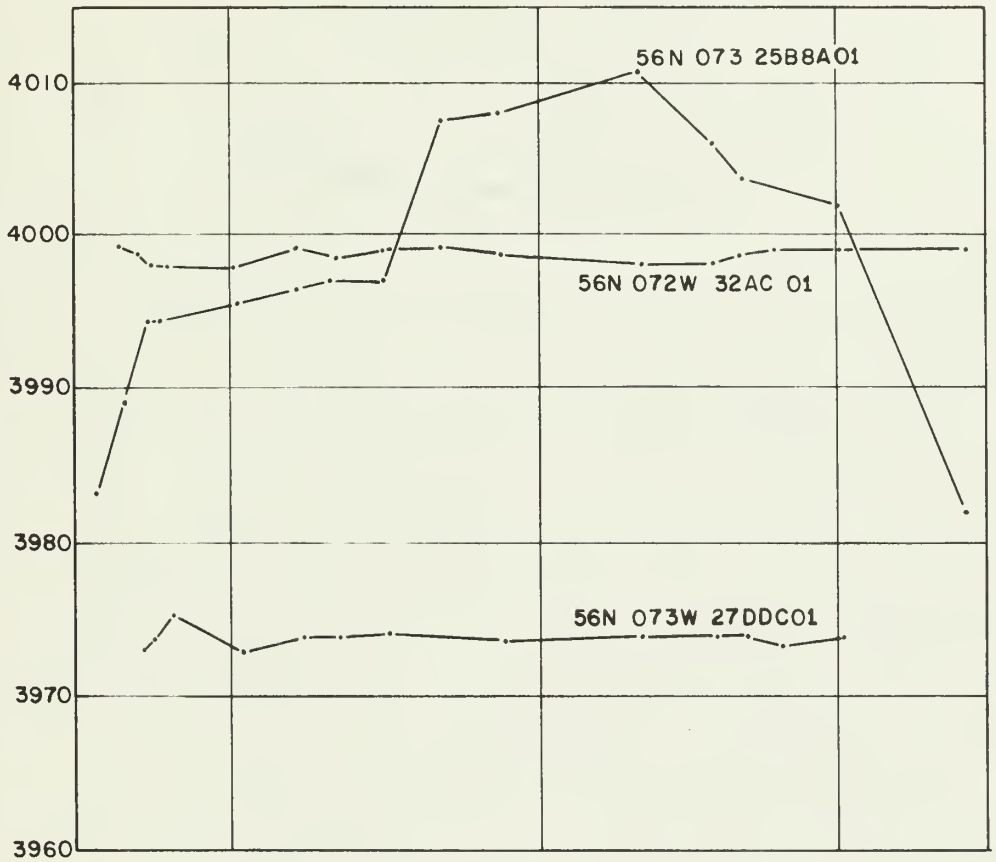
The long-term impacts will depend on the method of resource recovery and the reclamation practices. Although any known method of coal-resource recovery is possible, it is assumed for the purpose of discussion that there will be a multiple stripping operation and that the land will be reclaimed for grazing by methods described in other mine plans for eastern Campbell County in 1978.

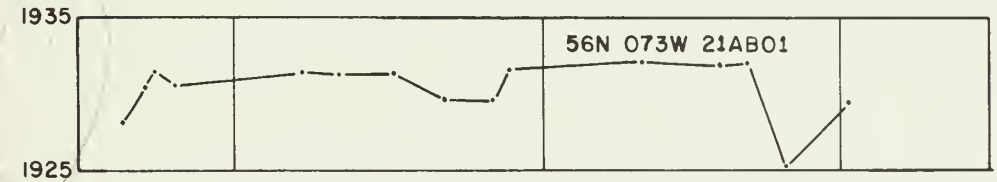
The coal will be removed and aquifers that occur above the coal will be destroyed. During reclamation, these aquifers will be replaced by spoil. Where the overburden-coal ratio is such that bulking of the spoil permits restoration of the original land surface, water levels in at least the deeper aquifers adjacent to those destroyed by mining may not be affected. More likely, there will be an effective retreat of the escarpment where the coals crop out, and water levels in the lateral equivalents to the destroyed beds will adjust to a new boundary. The quality of water in the



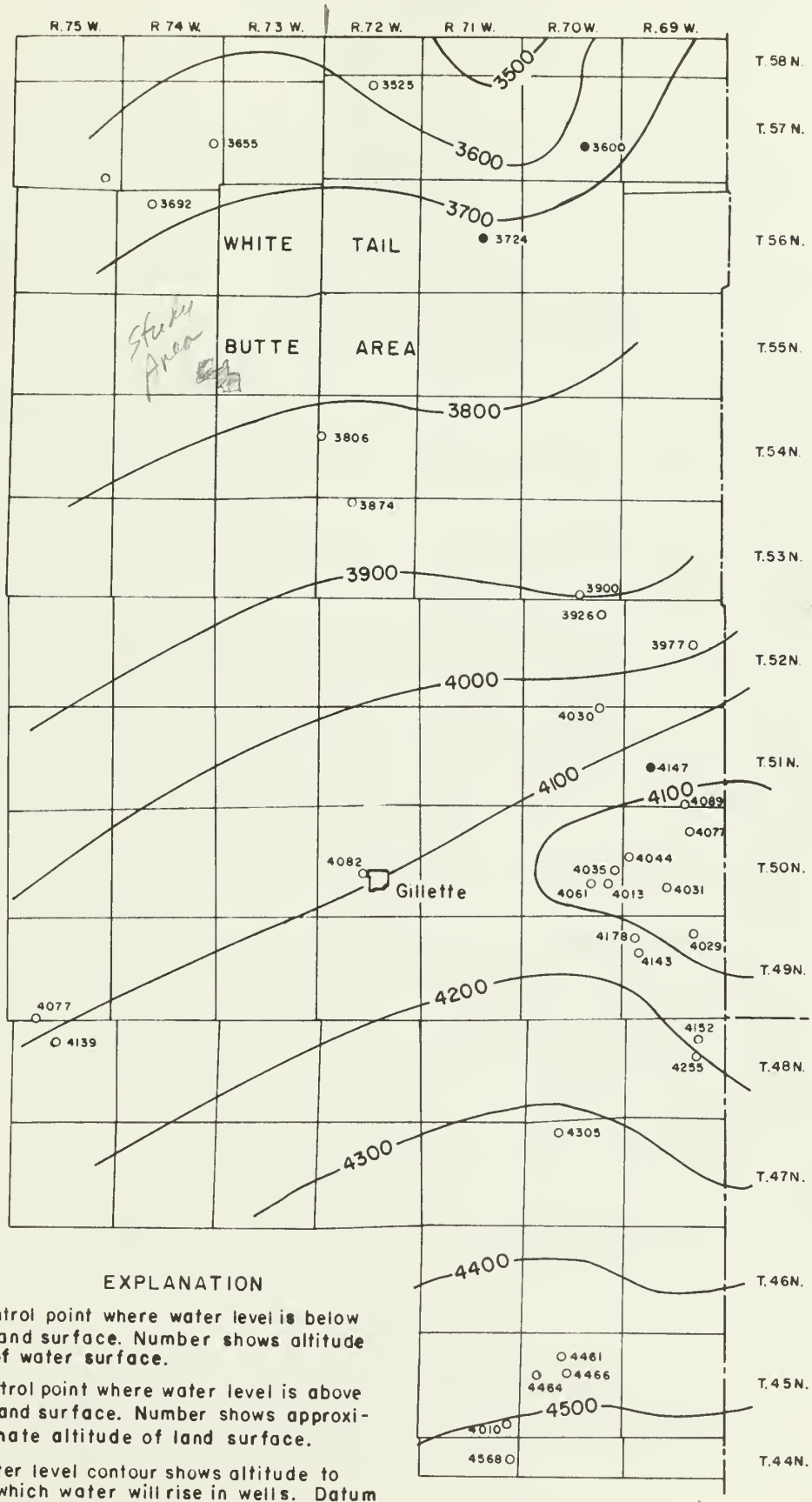

Percentage of cations and anions in ground water

White Tail Butte Area




Water levels in Piezometers in the Canyon Coal




EXPLANATION

○4077 Control point where water level is below land surface. Number shows altitude of water surface.

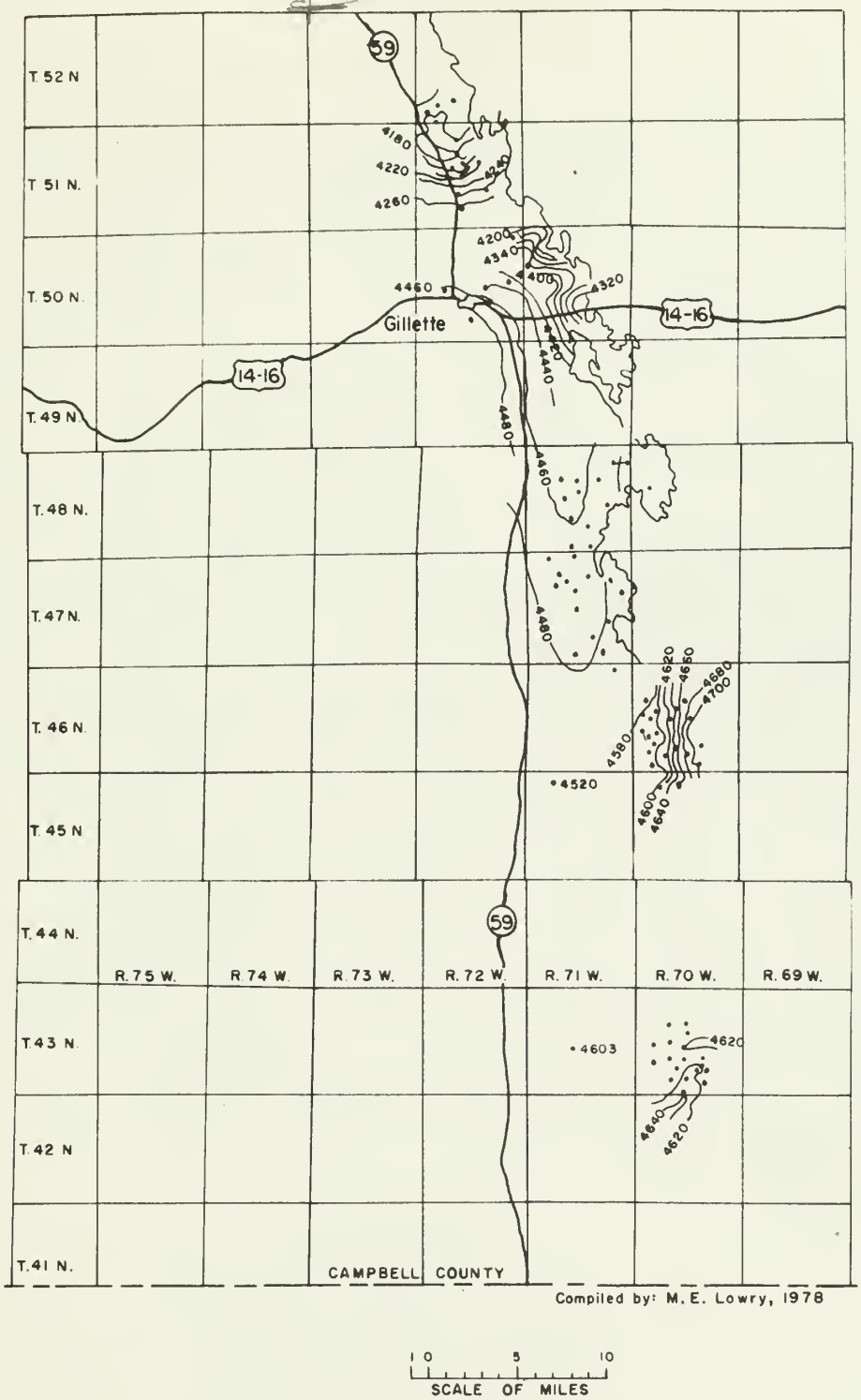
●3600 Control point where water level is above land surface. Number shows approximate altitude of land surface.

—4100— Water level contour shows altitude to which water will rise in wells. Datum is mean sea level.

1 0 5 10
SCALE IN MILES

Source?

Generalized map of water levels in wells in the Fox Hills Sandstone, Lance Formation, and lower Fort Union Formation in the Gillette area.




• Well completed in the Wyodak Coal Seam.

—4620— Elevation of the water surface in the Wyodak Coal.

•4603 Elevation of water surface in a well distant from other control points.

Eastern edge of the Wyodak Coal Seam (northern part of map only), adapted from Denson and Keefer, 1974.

Water levels in the WYODAK COAL BED in Central and Southern Campbell County, Wyoming

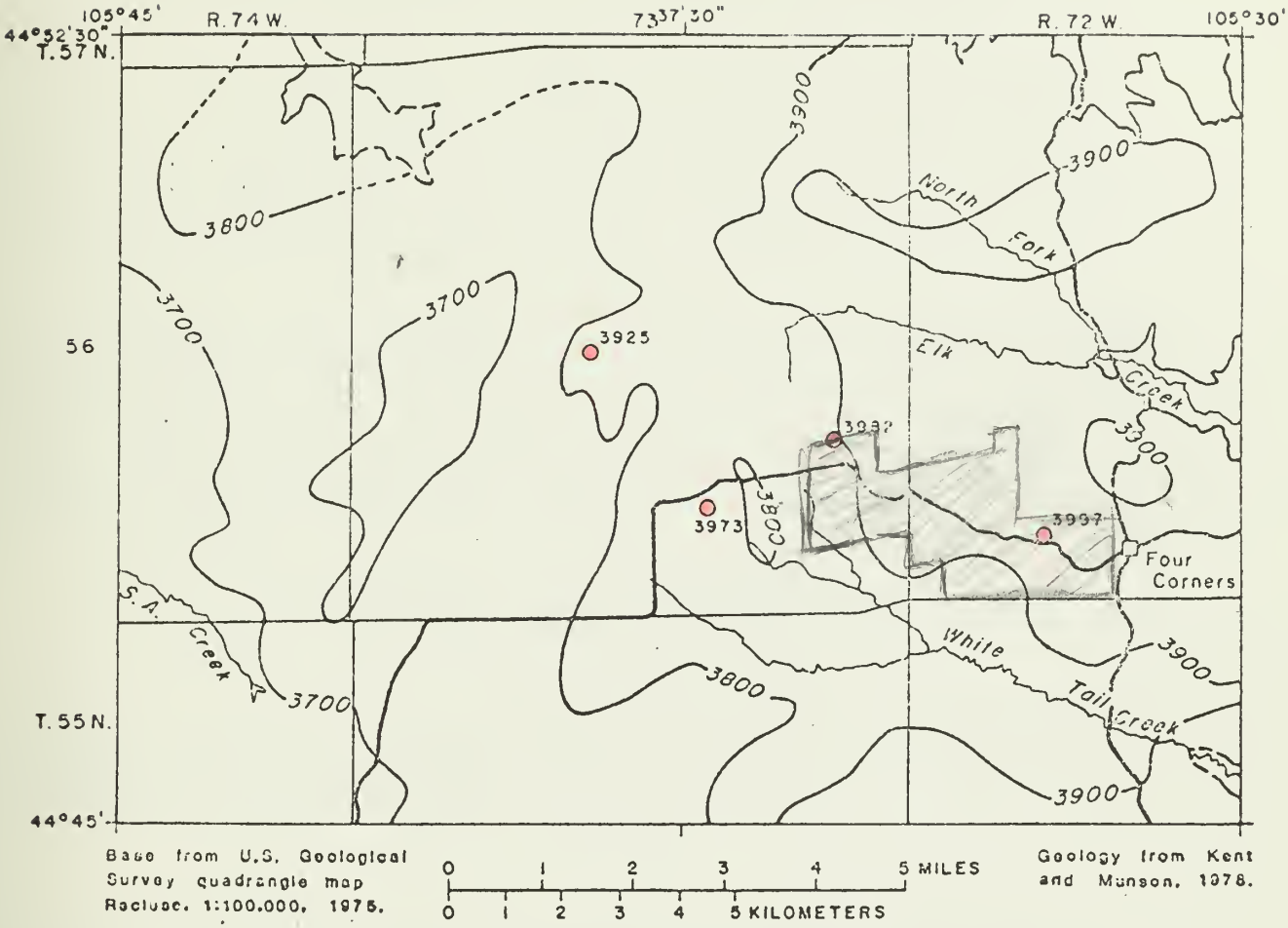



Figure 52--Relationship of the potentiometric surface in the Canyon coal to the coal.

Study Area

EXPLANATION

3800

Structure contour showing altitude, in feet, of the top or base of the Canyon coal and locally associated beds. Dashed where approximately located.

?

Outcrop of Canyon coal bed. Dashed where approximately located.

3997

Altitude of potentiometric surface

lateral equivalents of the disturbed aquifers and the deeper aquifers will not be affected because the direction of flow will be unchanged.

Soil permeability will probably be reduced as the result of mixing clay with the soil or soil material. However, the general lowering of the mean slope of the land surface and moisture-retaining measures, such as pitting and contour furrowing that are part of most reclamation plans, will increase infiltration. This may cause a net increase in infiltration at most existing mines in Campbell County. However, infiltration at White Tail Butte may be decreased if the area of exposed clinker is decreased.

The spoil will not have the relatively continuous, impermeable shale layers of the original deposits; therefore, water will move vertically with greater ease, and springs and seeps will not occur on hillsides in reclaimed areas. Water from local recharge and regional movement will be discharged at topographic lows, probably at the present drainages. The water-bearing properties of the spoil from coarse-grained overburden may be equivalent to those aquifers it replaces (Rahn 1976, p. 54). However, the quality of the water in the spoil will probably be similar to that in the present alluvium.

## Availability of Water for Reclamation and Post-Reclamation Use

### Surface Water

At present there are stock ponds on small draws and some flood irrigation on the major drainages. The availability of water for future use, as the availability is changed by mining, cannot be estimated.

### Ground Water

Water of suitable quality for irrigation, such as that which occurs in alluvium, clinker, and sometimes at shallow depth in bedrock, is not available in adequate quantities. Water in deep aquifers, where supplies adequate for supplementary irrigation can be obtained, has a high sodium-absorption ratio and therefore has restricted use.

The quantity and quality of water in aquifers that are lateral equivalents of those disturbed will not be greatly affected by mining, and deeper aquifers will not be affected. It may not be necessary to drill deep wells in the mined area to replace the springs that will be destroyed. A mine will undoubtedly drill a deep well for a potable supply, and this well can perhaps be used to supply stock and domestic water. In some areas in Wyoming where it is necessary to drill deep wells to obtain suitable stock and domestic supplies, one well is sometimes drilled and the water distributed by pipeline rather than drilling a number of deep, expensive wells. A similar technique could be used in the reclaimed areas.

Such a distribution system, although it would fill the need for stock water, would require maintenance. If the cost-benefit ratio is favorable or it is desired to restore springs in the uplands, clinker could be stockpiled

separately and replaced on impermeable membranes in predesigned catchment areas to restore the shallow, perched aquifers. Techniques for use of the membranes are currently being investigated for protection of the water table below sanitary land fills, and the reverse application would be equally valid.

## WILDLIFE

The study area falls within the upper Missouri River and Broken Lands physiographic region and the wheatgrass-needlegrass (Agropyron-Stipa) vegetation type as described by Kuchler (1964). Major plant species present include big sagebrush (Artemisia tridentata), bluebunch wheatgrass (Agropyron spicatum), western wheatgrass (Agropyron smithii), blue grama (Bouteloua gracilis), and threadleaf sedge (Carex filifolia). Numerous other grass, forb, and shrub species occur with lesser frequency.

The dominant big game species found in this area are pronghorn antelope and mule deer. The major upland game species in this study area is the sage grouse. Other species common to the sagebrush-grass biome which may occur in this area include the desert cottontail, Brewer's sparrow, horned lark, western meadowlark, rough legged and ferruginuous hawks, and wintering golden eagle.

The only specific aquatic habitat in the area is a six-acre livestock reservoir in T. 56 N., R. 73 W., Section 26, SE¼SE¼, that contains a stocked population of 12- to 14-inch rainbow trout.

If surface mining occurs in the White Tail Butte Study Area, Wyoming law will require the coal mine operator: "to restore wildlife habitat, whenever possible, on affected land in a manner commensurate with or superior to habitat conditions which existed before the land became affected; unless the land is used for a recreational or agricultural purpose which precludes its use as wildlife habitat." 1/

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1/ State of Wyoming, Department of Environmental Quality, 1978. Land Quality Rules and Regulations, Chapter 2, Section 1, b.(3).

## CULTURAL RESOURCES

The evidence of prehistoric occupation of the White Tail Butte Study Area identified during an inventory conducted in 1976 consisted of five sites and four isolated tools or stone flakes. Remains of two individual bison with no cultural association were also observed. None of the identified cultural values is eligible for nomination to the National Register of Historic Places, and no additional archeological work is needed.

Two of the sites identified consisted of individual tipi rings: one on top of White Tail Butte and one on a bench at its west end. Both tipi rings were constructed of large scoria fragments ranging in diameter from 30 to 50 centimeters. The tipi rings themselves are 2.5 meters in diameter. The other three sites consisted of small lithic scatters located on small benches around White Tail Butte. Since no diagnostic artifacts were located during the inventory, the occupation of the study area cannot be dated.

Ninety percent of the lithic materials located on the five sites consisted of porcelanite and fused glass material which is a distinctive lithic material of coal burn areas and occurs naturally in the scoria or baked shale on White Tail Butte. The use of porcelanite as a tool stone has been dated throughout the past 8,000 years in the Powder River Basin.

The two isolated bison remains were located in two head cuts, 2 meters below the surface. These remains lacked any cultural affiliation; however, they do indicate that other cultural remains may be deeply buried in the valley bottoms around White Tail Butte.

## RECREATION AND VISUAL MANAGEMENT

The White Tail Butte Study Area is within a relatively high value deer and antelope hunting area. There is some limited fishing opportunity in the stocked livestock reservoir. Because of the distance from perennial streams and settled areas, other recreational use is limited. Public access to the area is provided by a county road that passes through the site.

A visual resource management survey of the area resulted in a classification of IV. This indicates an area of relatively low visual resource value. It is an area where man's activities will not detract from the aesthetics.

## CONCLUSIONS

### CLIMATE

In general, the continental-type climate of the White Tail Butte Study Area appears favorable for revegetation of surface-mined land with native range plants. The pre-growing season moisture, 2.1 inches, is stored in the root zone and, when combined with the principal growing season precipitation of 7.2 inches, promotes rapid growth of native grasses. The spring rains usually exceed the plant moisture requirement, allowing soluble salts to be leached below 2 feet in depth in permeable soils.

The growing season for hardy crops is estimated at 136 days between mid-May and mid- to late-September. However, native range plants usually deplete the available soil moisture by mid-July and mature or become dormant.

Climatic factors that may adversely affect revegetation efforts in this study area include: (1) below normal or uneven distribution of rainfall, especially during the growing season, (2) thunderstorms and/or strong winds that cause erosion, (3) late spring freezes, and (4) depletion of soil moisture by wind.

### PHYSIOGRAPHY

The White Tail Butte Study Area lies in the unglaciated portion of the Great Plains physiographic province. The topography is characterized by rolling and rather thoroughly dissected uplands, with several prominent buttes capped by resistant "clinker" rising above a tabular divide which generally trends in a northwesterly direction through the study area. The most prominent of these buttes is White Tail Butte, located in sections 31 and 32, T. 56 N., R. 72 W.

Dendritic drainages in the study area empty northward into Elk Creek and southward into White Tail Creek. Both creeks are intermittent tributaries to the Little Powder River. Most drainages within the area are deeply incised into shales and sandstones of the Wasatch (Eocene) and Fort Union (Paleocene) Formations.

### GEOLOGY

The White Tail Butte Study Area is in the eastern part of the Powder River Basin. This deep sedimentary basin is about 225 miles long and 90 miles wide. It extends from the Yellowstone River in Montana to the North Platte River in Wyoming and from the Black Hills of South Dakota to the Bighorn Mountains of Wyoming.

Sedimentary strata exposed in the study area are members of the Fort Union Formation of Paleocene Age and the Wasatch Formation of Eocene Age. Alluvial deposits of Holocene Age mantle valley floors of the major tributaries.

Twelve persistent coalbeds crop out or were penetrated by drilling in the study area. Three coalbeds of economic significance occur within 200 feet of the surface. They are the Anderson, Dietz, and Canyon coalbeds. The Anderson

averages about 34.3 feet thick. The Dietz splits in the area and ranges from over 28 feet thick in Drill Hole 76-102 to a combined thickness of 18 feet in two benches in the western part of the area. The Canyon coalbed averages 21.6 feet thick.

Engineering property tests performed on bedrock materials similar to those in the White Tail Butte Study Area revealed that shear strengths are low. Slides can develop adjacent to high walls in surface mines, and saturated alluvial deposits and uncemented siltstones and fine-grained sandstone will readily erode and flow into excavations.

Excavation slopes will vary between minesites and will be dependent on exposure time, moisture conditions, material types, and depth of cut.

After disturbance, an increase of about 25 to 30 percent will occur in the volume of the overburden. Some areas of the surface will actually be higher in elevation after mining. Settlement will then occur for several years after reclamation, until volumes are again reduced to a stable condition.

Three types of postmining landscape instability may occur on reclaimed land in the White Tail Butte Study Area. These are: (1) area-wide settling, (2) localized collapse, and (3) piping. Each form of instability is affected by certain variables in the postmining landscape. These variables include the physical and chemical characteristics of the overburden, methods and equipment used in spoil contouring operations, and the season when these activities occur.

Weathering tests conducted on geologic core samples from the White Tail Butte Study Area showed that shale samples swelled and broke down readily under saturated conditions. Handling these clay-rich materials in a moist condition may be difficult due to their plastic characteristics. Sandstone and siltstone samples were more resistant to weathering. These materials appeared to break down more easily under freeze-thaw conditions than under wet-dry conditions.

A study of the seismic history of the region indicates that minor damage could result to structures from earthquake shocks.

## COAL RESOURCES

The White Tail Butte Study Area is located in the Little Powder River Coalfield. Three coalbeds are economically significant. They are part of the Tongue River Member of the Fort Union Formation of Paleocene Age. They generally lie within 200 feet of the surface and are, in descending order, the Anderson coalbed, the Dietz coalbed, and the Canyon coalbed.

Coalbeds in the study area were evaluated by 8 core holes ranging from 275 to 785.5 feet deep. Total measured and indicated coal resources for the Anderson, Dietz, and Canyon coalbeds that lie within 200 feet of the surface are:

| | |
|---|---|
| Anderson coalbed | 94,464,000 short tons |
| Dietz coalbed | 35,185,000 short tons |
| Canyon coalbed | 24,775,000 short tons |

A total of 66 coal samples from the Anderson, Dietz, and Canyon coalbeds in the study area were tested. The heat of combustion (as received basis) ranged from 6,778 Btu/lb to 7,617 Btu/lb. The ash content (as received basis) averaged about 7.03 percent. The sulfur content (as received basis) averaged about 0.49 percent. The apparent rank of the samples ranged from Lignite 'A' to Subbituminous 'C'.

## OVERBURDEN - SOIL AND BEDROCK

Data considered in determining the usable overburden material (soil and bedrock) for use in revegetation included: quality, quantity, ease of stripping and stockpiling, and other factors directly affecting their use for revegetation.

Based on the results of the land suitability survey, the natural mix of residual and deep colluvial/alluvial soils in the White Tail Butte Study Area should provide an adequate supply of suitable topsoiling material for revegetation, if surface mining occurs.

The A and B horizons of most soils in this study area will provide the best material available for resurfacing shaped spoils. Generally, they are nonsaline, nonsodic, and permeable. Most of the soil organic matter is contained in these horizons. Stripping these horizons separately appears impractical because the A horizon is typically only 2 to 6 inches thick. In A-C soil profiles, the upper portion of the C horizon is often comparable to the B horizon of other soils for use as plant media.

Soluble salts have been leached to a depth of about 2 feet in deep, loamy soils with good permeability. For most soils in this area, this includes the A, B, and part of the C horizons. Soluble salts often remain near the surface in shallow A-C soils, seep areas, and saline-sodic soils.

Local tracts of clay-rich, saline, or saline/sodic soils will require borrowed soil material from adjacent lands with adequate suitable material.

Although the consolidated bedrock in the study area should break down readily upon weathering, it is generally unsuited for use as plant media at or near the surface in reconstructed profiles. Notable deficiencies of the bedrock materials include: high salinity and/or sodicity, slow permeability, fine texture (clay-rich), and erodibility.

### Moisture Relations in Soils

The White Tail Butte Study Area is traversed by an east-west trending relict surface with the land sloping away to the north and south. Slope gradients can be used to separate colluvium from residuum and alluvium. Colluvium is associated with slopes exceeding $10^{\circ}$, whereas residuum and alluvium are associated with slopes ranging from 1 to $8^{\circ}$. Grasses predominate over shrubs in areas with residual soils because drainage is impeded by bedrock. Shrubs predominate over grass on alluvium, because the alluvium is well drained. As a result, more force must be exerted to obtain water than when water is stored in thicker films. Bedrock also impedes drainage beneath colluvium and areas covered by thin baked rock (clinker). This results in a cover of grass rather

than shrubs. Grasses predominate in swales or other low areas having good drainage, because larger quantities of water are stored in those soils. The extra water is derived from upstream runoff or from snow blown in from higher areas.

The alluvial soil materials have the most optimum moisture-retention characteristics of the several materials available for revegetation.

## GREENHOUSE

Western wheatgrass was grown on selected soil and bedrock samples from the White Tail Butte Study Area. Relative yields were calculated as a percentage of the yields produced on a standard soil (Platner) and were rated as follows: 0-33 percent - low, 34-67 percent - medium, and above 67 percent - high.

Relative yields for 10 percent of the bedrock samples were low, 44 percent were medium, and 46 percent were high. However, samples with relatively high yields may not be suitable for use as plant growth media under field conditions. This material is often fine-textured (clay-rich) and virtually impermeable. Also, some samples are saline and/or sodic.

Relative yields for 12 percent of the soil samples were low, 66 percent were medium, and 22 percent were high. The samples which produced low yields were generally saline. Overall, the majority of soil samples showed favorable physical and chemical characteristics for use as revegetative media.

## VEGETATION

Topographic variation (slopes and exposures) and a variety of soil parent materials in the area provide habitats for a number of contrasting plant communities. These include grasslands, shrublands, and a tree type. Vegetation types sampled include: (1) silver sagebrush-green needlegrass, (2) bluebunch wheatgrass, (3) blue grama-big sagebrush, (4) western wheatgrass-blue grama, (5) big sagebrush-western wheatgrass, (6) bluebunch wheatgrass-big sagebrush, (7) big sagebrush-bluebunch wheatgrass, and (8) ponderosa pine-little bluestem.

Most of the vegetation types were considered to be in good to excellent condition, but some were in fair to good range condition. Yields for the different types were 446 lbs/acre for the least productive (bluebunch wheatgrass-big sagebrush) and 1380 lbs/acre for the most productive (silver sagebrush-green needlegrass). Carrying capacities ranged from 1.4 acres per animal unit month for the silver sagebrush-green needlegrass type to 6.2 acres for the big sagebrush-western wheatgrass type.

## HYDROLOGY

### Surface Water Hydrology

Two small basins, North Divide Draw and Elk Creek tributary, were used for samples to study surface water hydrology of the White Tail Butte area. The two basins are similar in size and topography but different in areal extent and the distribution of exposed clinker.

Total annual runoff from North Divide Draw and Elk Creek Tributary was 61.0 acre-ft and 19.2 acre-ft, respectively. Runoff from snowmelt produced about 5 percent of the annual runoff from a snowpack which contained about 240 acre-ft of water. The remainder of runoff was produced by high-intensity convective storms. Rainfall-runoff models were calibrated for the two basins using rainfall and runoff data collected during the summers of 1976 and 1977. Model parameters defined by the calibration process were used with long-term precipitation and evaporation records to simulate 73 years of peak discharge and volume data. The long-term data, collected at Cheyenne, were adjusted to represent the climate of the White Tail Butte area.

Log-Pearson Type III probability distribution was applied to the 73 years of simulated data to define the magnitude versus frequency-runoff curves for the two basins. Results of the study show that an increase in area of exposed clinker reduces runoff.

The runoff estimated by the use of the rainfall-runoff model for North Divide Draw is 19 to 33 percent greater than that estimated from equations based on basin characteristics. Runoff estimated for Elk Creek tributary is 80 to 88 percent less.

Impacts of surface mining on runoff could not be evaluated, but sensitivity of runoff to infiltration was investigated. The study shows that for a 1-percent change in infiltration, runoff changes inversely by about 10 percent.

## Hydrologic Classification of Land Types Using Rainfall Simulation

Simulated rainfall at an intensity of about 2 in/hr was applied to four very small watersheds, 2,000 to 3,000 $ft^2$ in area. Runoff and sediment yield were very low from a moderately steep, well-grassed watershed underlain by baked rock (clinker). Runoff was moderate, but sediment yield was low from a watershed in an upland swale that was well-grassed. An area with fine-textured soil and about 66 percent cover of sagebrush and grass produced high runoff, but sediment yield was fairly low. Runoff was high and sediment yield was moderate from an eroding area that had about 51 percent cover of grass and sagebrush.

## Sediment Yields

Estimated sediment yields from source areas are variable owing to differences in surficial materials and relief, and the associated amount of vegetation cover. Low annual sediment yields (0 to 0.35 acre-ft/$mi^2$) occur from bottomland alluvium, mesas and clinker-mantled rolling plains, all of which have good to excellent vegetation cover. High sediment yields (1.4 to 2.3 acre-ft/$mi^2$) occur from steep, dissected, relatively barren hillslopes underlain by erosive sedimentary rocks. Channel erosion by headcutting appears to be significant in some of the draws in those areas. Moderate sediment yields (0.36 to 0.75 acre-ft/$mi^2$) occur from hill-and-valley areas with a mixture of two or more of the above-mentioned surficial materials. Those areas have more vegetation and are less dissected than the high-yielding areas. Estimated sediment discharges from small drainage basins, 0.28 to 2.13 $mi^2$ in size, range from 0.04 to 1.53 acre-ft/$mi^2$. The variations are caused by differences in sediment production from source areas within the basins and differences in sediment transport efficiencies of the main channel systems.

## Ground Water Hydrology

Work in Campbell County has resulted in a conceptual model of ground-water movement in the aquifers more than 1,000 feet deep and for movement in the Wyodak coal. Movement in the deeper aquifers is northward in the northern part of Campbell County, as determined from a potentiometric map of deep wells open to one or more of the Tullock Member of the Fort Union Formation, the Lance Formation, and the Fox Hills Sandstone. It is not definitely known if the water levels in the deep wells represent the same potentiometric surface, but the contours agree with a potentiometric map for the Fox Hills-Lance aquifer to the north in Montana (W. R. Miller, oral commun. 1978). The results of the study in the White Tail Butte area are consistent with the regional model of movement in the deeper aquifers because heads increase with depth in the Tullock Member of the Fort Union Formation north of Weston, Wyoming.

The potentiometric surface in the Wyodak coal, which is equivalent to the Anderson and Canyon coal of the White Tail Butte area, indicates there is recharge at the coal outcrop from the southern part of Campbell County as far north as T. 46 N. and that the coal outcrop near Gillette is a discharge point. The water levels in piezometers completed in the Anderson and Canyon coals in the White Tail Butte area are higher than nearby outcrops of the coals, indicating it is also a discharge area.

Although the White Tail Butte area seems to be a discharge point for part of the regional flow, the amount of water being discharged from the regional system in the area is small compared with water moving locally through the system. Water of a sodium-bicarbonate type with dissolved-solids concentration greater than 1,000 mg/L generally occurs in the aquifers where water has moved through them for distances of a few miles. However, neither the water sampled from springs nor that sampled from alluvium contained this combination of high bicarbonate and dissolved solids. This indicates that the water had not moved a great distance through the bedrock aquifers.

If surface mining occurs, hillside springs will be destroyed in the mined area and will not be restored unless special reclamation procedures are used. However, aquifers occur below the coal so there is enough water of suitable quality to reclaim the land for livestock grazing, which is the present land use.

## WILDLIFE

The dominant big game species occurring in the White Tail Butte Study Area are pronghorn antelope and mule deer. The major upland game species in this study area is the sage grouse. Other species common to the sagebrush-grass biome which may occur in this area include the desert cottontail, Brewer's sparrow, horned lark, western meadowlark, rough-legged and ferruginous hawks, and wintering golden eagle.

The only specific aquatic habitat in the area is a 6-acre livestock reservoir in T. 56 N., R. 73 W., Section 26, SE¼SE¼, that contains a stocked population of 12- 14-inch rainbow trout.

## CULTURAL RESOURCES

The evidence of prehistoric occupation of the study area identified during an inventory conducted in 1976 consisted of five sites and four isolated tools or stone flakes.

Two of the sites identified consisted of individual tipi rings; the other three sites were composed of small lithic scatters located on small benches around White Tail Butte. Remains of two bison were also observed.

None of the identified cultural values is eligible for nomination to the National Register of Historic Places, and no additional archeological work is necessary.

## RECREATION AND VISUAL MANAGEMENT

The White Tail Butte Study Area lies within a relatively high value deer and pronghorn antelope hunting area. Also, limited fishing opportunity is available from a stocked livestock reservoir. Because of the distance from perennial streams and settled areas, other recreational use is limited.

A visual resource management survey of the study area resulted in a classification of IV. This indicates an area of relatively low visual resource value.

## RECOMMENDATIONS FOR RECLAMATION

Special consideration should be given to the following factors when developing a reclamation plan for the White Tail Butte Study Area: (1) stability of the postmining landscape, (2) restoration of water resources, (3) erosion control, and (4) revegetation.

### STABILITY OF THE POSTMINING LANDSCAPE 1/

The design of stable postmining landscapes will require the integration of several critical factors: These include: (1) a detailed knowledge of the distribution of overburden materials, with emphasis on the delineation of highly sodic spoils, (2) proper equipment selection, and (3) a consideration of seasonal factors. For reclamation to be successful, consideration must be given to the entire landscape, not merely the soil zone.

Three forms of landscape instability are common on reclaimed coal-mined areas in the Northern Great Plains. These are area-wide settling, local collapse, and piping.

Area-wide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This form of subsidence will generally be most pronounced during the first year following reclamation and will continue at a decreasing rate for a number of years. The two major factors influencing area-wide settling are: (1) texture of the overburden, and (2) equipment used in spoil contouring operations.

Fine-textured overburden usually results in more blocky and, initially, more porous spoils than does coarse-textured overburden. Therefore, a lesser degree of area-wide settling can be expected in areas of largely sandy spoils than in areas of largely clayey spoils.

Equipment used in contouring operations is a critical factor influencing area-wide settling. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas due to the fact that scrapers more effectively break down large overburden blocks and compact the spoil mass. Therefore, the degree of area-wide settlement may be reduced by employing scrapers rather than dozers in spoil contouring operations.

Local large-scale collapse often develops soon after contouring is completed. Development typically ends within one year. This form of instability is predominant in precontouring valleys where large, frozen spoil blocks are concentrated by mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. To restrict the development of local collapse features, the use of scrapers rather than dozers should be considered for contouring operations during the winter months.

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1/Groenwold, G.H. and Rehm, B.W., 1980.

Piping appears to be a severe and long-term problem in some postmining landscapes. This form of instability usually begins soon after contouring ceases and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as five years.

Piping is apparently controlled by a combination of physical and chemical conditions in the spoils. All piping begins as a crack, either on the surface of exposed spoils or at the topsoil-spoil interface. In the latter case, the overlying topsoil collapses into the pipe and is carried away. Repeated topsoil application is usually unsuccessful in stopping the growth and development of piping. Cracking of spoils is restricted to areas of highly dispersive sodic materials. The cracks allow access for large volumes of surface runoff to flow into the subsurface of the spoils. However, surface cracking alone will not necessarily result in the development of piping. Piping will develop only if an avenue for water movement can result from fracturing within the mass of spoils due to differential settling between differentially compacted areas (i.e., scraper-contoured area adjacent to dozer-contoured area) or within areas of poorly compacted spoils (i.e., dozer contouring only).

Piping usually develops in nearly flat areas, where runoff is minimal and infiltration is maximized. Thus, the final surface slopes in reclaimed areas must also be recognized as controlling factors in the development of piping.

Given the proper conditions of slope, near-surface dispersive materials, and a permeable zone in the base of the spoils, piping may continue to develop and disrupt postmining landscapes for many years. Selective handling of highly sodic overburden may prove to be the only effective means of controlling piping in many areas in the Northern Great Plains.

Because postmining landscapes tend to be unstable, structures should not be built on reclaimed lands unless they are specifically designed to absorb differential settlement. Also, reconstructed drainage channels will require periodic maintenance to ensure that ponded areas to not develop in areas of localized settlement.

## RESTORATION OF WATER RESOURCES

### Surface Water

The overall objective for surface water in the reclamation plan should be to restore the pre-mining hydrologic function of the site. However, there are opportunities during the reclamation phase to improve upon the pre-mining surface water resource, particularly from a runoff timing standpoint.

Rapid establishment of a grass cover on critical watershed slopes and channel areas is the first prerequisite in achieving a stable watershed. Channel areas should be seeded to sod-forming grasses to achieve grass-lined waterways. Transplanting native sod to these waterways should be considered.

The objective in channel reconstruction should be to decrease channel gradients and increase width/depth ratios so that flow velocities are decreased. The storage capacity of the replaced "alluvium" in channel areas should be duplicated or increased over pre-mining conditions to insure adequate base flows. The material used to replace the alluvium should have approximately the same (or better) geochemical properties. The channel reconstruction and alluvium replacement will facilitate rehabilitation of the riparian and woody draw ecosystems that are found in the study area.

Contour furrowing, gouging, or similar land treatments should be applied to the steeper reclaimed slopes to promote infiltration, increase retention storage, and decrease flood volumes.

If stock and wildlife water impoundments are included in the lease stipulations, these structures should be designed so as to also function as runoff control structures.

Runoff from the study area is currently supplying water for stock ponds and flood irrigation below the study area. Provisions for maintaining these water supplies, both quantity and quality, should be included in the lease stipulations. No large water retention structures should be built above the existing structures.

## Ground Water

It can generally be assumed that aquifers located above the deepest coal seam to be mined will be destroyed. Also, springs and seeps will probably not occur on hillsides in the reclaimed area because the replaced overburden will not have the relatively continuous bedding of the original sedimentary deposits. Aquifers that lie below the mined area will not be disturbed. Those that lie outside the mined area, and are lateral equivalents of disturbed aquifers, should also not be greatly affected.

Ground water recharge capacity in the reclaimed area will depend on such factors as: (1) postmining topography, (2) properties of the overburden materials, and (3) the moisture conservation techniques employed.

If surface mining occurs in this study area, the existing topography will probably be reshaped to a more gently sloping condition. This would allow a greater percentage of infiltration in the reclaimed area. Therefore, the rate of recharge to deep aquifers would be increased. However, this increase would be difficult to quantify.

The properties of the overburden materials are important factors influencing recharge capacity. The fractured state of the spoils initially will allow for increased recharge of deep aquifers as water percolates freely downward under gravitational force. However, as weathering and subsidence of spoils occur, impermeable layers may develop which will limit the rate of recharge to deep aquifers. In local areas, "perched" aquifers could develop above these impermeable strata.

Implementation of such moisture conservation techniques as contour furrowing, gouging, pitting, etc., may also influence the amount of ground water recharge. The objective of these techniques is to reduce runoff and maximize infiltration. If one or more of these measures is employed on reclaimed land in this study area, recharge capacity should be improved due to the increase in infiltration.

The ground water supply that will be available in the reclaimed area is difficult to estimate. To obtain suitable stock and domestic water supplies, it may be advantageous to drill one main well to a deep aquifer and distribute the supplies through a pipeline system to selected locations. From an economic standpoint, this technique appears more desirable than drilling a number of deep, expensive wells.

## EROSION CONTROL

One or more of the following conservation practices may be employed on reclaimed land in the White Tail Butte Study Area to control erosion and minimize sediment loading to receiving streams: (1) reducing the mean surface slope of the area, (2) lining reconstructed drainage channels, (3) gouging, (4) pitting, (5) terracing, (6) contour furrowing, (7) mulching, and (8) establishing a permanent vegetative cover on topsoiled areas as quickly as possible.

If surface mining occurs in this study area, reshaping the postmining topography to a more gently rolling condition should be considered. By reducing the mean surface slope in the reclaimed area, the potential for runoff and erosion would be reduced. Also, the quantity of soil moisture available for plant use would be increased due to an increase in infiltration.

To minimize the potential for gully erosion and severe soil losses, reconstructed stream channels should be lined with a durable rip-rap material or a vegetative cover of adapted plant species. If possible, riparian vegetation in the study area should be removed prior to mining and replaced in the reconstructed drainages. Another technique which could be employed to retard gully erosion in reconstructed drainages would be to widen the stream channels. This would cause flows to be shallower and less erosive.

On slopes exceeding 5 percent in the reclaimed area, it is strongly recommended that closely-spaced contour furrowing, gouging, pitting or terracing be employed to minimize erosion and reduce sediment yields. These practices are very effective in capturing precipitation that might otherwise be lost in runoff. Thus, runoff and erosion are reduced, while the amount of soil moisture available for seed germination and plant development is increased.

To comply with Wyoming law, mulch or other suitable soil stabilizers (i.e., chemical binders) must be applied to all topsoiled areas in order to conserve soil moisture and control erosion. If straw or hay mulch is applied, it should be disked or "crimped" (cutaway roller disk) into the soil surface to prevent substantial losses of the material due to blowing.

Annual grains or grasses may be substituted for, or used in conjunction with, another mulch if the Wyoming Department of Environmental Quality determines that they will provide adequate erosion control and will be later replaced by perennial species approved for the postmining land use. Recent investigations in Wyoming have shown that standing stubble (in situ mulch) from spring planted small grains is slightly more effective in controlling erosion on topsoiled areas than crimped straw.[2/] Furthermore, areas protected by standing stubble show higher infiltration rates and lower diurnal fluctuations in soil temperature - both factors being very important to seed germination and plant growth. Based on this data, and the fact that the cost of providing standing stubble is substantially less (75 to 95 percent) than using crimped straw, the use of stubble as an alternative mulch should be considered for reclaimed lands in the White Tail Butte Study Area.

Probably the most effective method of controlling erosion on topsoiled areas is establishing a permanent vegetative cover as quickly as possible. If a permanent cover can not be established within 45 days, a temporary cover of small grains, grasses, or legumes should be established.

## REVEGETATION

Revegetation of surface-mined land in the White Tail Butte Study area will require: (1) removal, segregation, and redistribution of suitable plant growth material, (2) proper grading of area surfaces, (3) selection of adapted plant species, (4) use of proper planting and seedbed preparation procedures, (5) application of fertilizer and/or soil amendments, and (6) management of the reclaimed area until vegetation has become permanently established.

### Removal, Segregation, and Redistribution of Suitable Plant Growth Material

Prior to the actual mining operation, all suitable plant growth material should be removed and segregated in separate stockpiles. Surface soil, because of its natural fertility, higher organic matter content, and stable structure, is usually the most suitable material available. However, this is not always the case. Surface soils on some lands may be clay-rich, slowly permeable, saline/sodic, and/or erosive. If the existing surface soil is determined to be unsuitable for revegetative purposes or is lacking in quantity, subsoil material may be utilized as a substitute for, or in addition to, the topsoil if approved by the regulatory authority (Wyoming Department of Environmental Quality - DEQ).

Topsoil or substitute revegetative material should be stockpiled separately following its removal unless it is to be redistributed immediately on regraded areas. Selective placement of the stockpiles will be necessary to protect the topsoil from contamination by toxic spoils. In order to minimize erosion, a quick-growing vegetative cover should be established on the stockpiles.

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2/Schuman, G.E., Taylor, E.M., et al, 1980.

After final grading (of spoils) and before the suitable plant growth material is respread, regraded land should be scarified or otherwise treated to eliminate slipppage surfaces and enhance root penetration. The redistribution of plant growth material should then proceed in a manner that: (1) achieves an approximate uniform thickness consistent with the planned postmining land use, (2) prevents excess compaction of the plant media, and (3) protects the plant growth material from wind and water erosion before sufficient vegetation is established.

## Grading of Area Surfaces

Wyoming law presently requires that: "All overburden, spoil material, and refuse piles must be designed, graded, and contoured so as to blend in with the topography of the surrounding terrain (slope requirements will depend on an average of the slopes of the surrounding area and on the nature of the material) . . . . The slopes of all spoil areas must be designed so that they will be stabilized against wind and water erosion. This may include terracing, channeling around the toe of the spoil piles, or other techniques." Furthermore, "Contouring of spoil piles must provide for drainage patterns that complement the surrounding terrain and provide for long-term stability."

Where possible, all final grading, preparation of regraded land before redistribution of topsoil, and placement of suitable surfacing material should be done along the contour to minimize erosion and increase stability.

## Selection of Adapted Plants

Plant species and seeding rates proposed for revegetation are subject to approval by DEQ. Seed types will depend on the climatic and soil conditions prevailing in the area to be revegetated and the proposed postmining land use(s). Species to be established as permanent cover should be self-renewing. Seeding rates will depend on seed type, climatic and soil conditions, and techniques to be used in seeding.

Introduced species may be substituted for native species if revegetation test plots show such species to be of equal or superior utility for reclamation purposes. The use of introduced species is subject to approval by DEQ.

Plant selection for revegetation is very important. Some considerations in selecting revegetative species for the White Tail Butte Study Area should include: drought resistance, salt and sodium tolerance, resistance to winterkill, palatability, and resistance to grazing pressure. Of equal importance is plant compatibility with soil type, slope, aspect, and drainage conditions.

The following seeding rates and mixtures are suggested for revegetation on: 1) loamy and clayey soils, and 2) sandy soils in the White Tail Butte Study Area 3/:

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3/ This data was obtained from the Soil Conservation Service, U.S. Department of Agriculture, Gillette, Wyoming.

Loamy - Clayey Soils

| | |
|---|---|
| Green Needlegrass | 3 lbs/acre |
| Rosanna western wheatgrass | 3 lbs/acre |
| Critana thickspike wheatgrass | 3 lbs/acre |
| Fourwing saltbush | 1 lb/acre |

Sandy Soils

| | |
|---|---|
| Goshen Prairie sandreed | 3 lbs/acre |
| Indian ricegrass | 3 lbs/acre |
| Critana thickspike wheatgrass | 3 lbs/acre |
| Fourwing saltbush | 1 lb/acre |

Alternate plants native to the Upland - Sagebrush, Ponderosa Pine, and Riparian (natural drainages) plant communities found in this area which may also be considered for revegetation include:

Upland - Sagebrush Plant Community

| | |
|---|---|
| Big sagebrush | Skunkbush sumac |
| Fourwing saltbush | Winterfat |
| Western wheatgrass | Green needlegrass |
| Indian ricegrass | Thickspike wheatgrass |
| Bluebunch wheatgrass | Prairie junegrass |
| Scarlet globemallow | Purple prairieclover |
| Prairie coneflower | |

Silver sagebrush
Little bluestem
Sand dropseed

Sandy areas

Ponderosa Pine Plant Community

| | |
|---|---|
| Ponderosa Pine | Skunkbush sumac |
| Juniper | Big sagebrush |
| Bitterbrush | Bluebunch wheatgrass |
| Mutton bluegrass | |

Riparian (Natural Drainages) Plant Community

| | |
|---|---|
| Wood's rose | Currant |
| Buffaloberry | Streambank wheatgrass |
| Prairie cordgrass | Western wheatgrass |
| Saltgrass | Cottonwood |
| Willow | |

Seeding/planting rates and mixtures should be selected on the basis of specific site conditions (i.e. - soil type, slope, aspect, drainage conditions, etc.).

## Planting and Seedbed Preparation

Topsoiled areas which have been severely compacted by heavy machinery should be ripped 18 to 24 inches before preparing the seedbed. Disking should then be conducted prior to seeding and/or planting. With proper seedbed preparation, successful germination and establishment of revegetative species will be enhanced.

Seeding and/or planting should be conducted during the first normal period for favorable planting conditions after suitable plant growth material has been spread. The normal period for favorable planting is that planting time accepted locally for the plant species selected to meet specific site conditions and climate.

Mechanical drill seeding is generally the preferred technique, but good stands may also be established by broadcasting or hydroseeding. If drill seeding is the selected method, it should be conducted on the contour to minimize erosion and increase the potential for moisture retention. In order to provide favorable growing conditions, seeds should be covered by about one-half inch of soil.

## Application of Fertilizer and Soil Amendments

In order to support the planned postmining land use(s) and meet all revegetation requirements, nutrients (fertilizer) and/or soil amendments should be applied to the redistributed surface soil layer in the amounts determined by soil tests.

All soil tests should be performed by a qualified laboratory using standard methods approved by the regulatory authority (DEQ).

## Management of the Revegetated Area

In Wyoming, the coal mine operator is responsible for management of the reclaimed area until such time as: (1) the vegetative cover on the disturbed area is capable of renewing itself under natural conditions prevailing at the site, and is at least equal to the cover on the area before mining, (2) the productivity is at least equal to the productivity of the area before mining, (3) the species diversity and composition are suitable for the land use goal, and (4) the requirements of (1), (2), and (3) are met for 2 consecutive years.

Assuming that range will be the primary postmining land use, young vegetative growth should be protected from livestock grazing by fencing or other techniques until the vegetation is capable of withstanding grazing pressure at least comparable to that which existed prior to mining.

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# APPENDIX A

# ENGLISH TO METRIC CONVERSIONS

## ENGLISH TO METRIC (SI) CONVERSIONS

A dual system of measurements--English units and the International System (SI) of metric units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

| Multiply English Units | By | To Obtain SI Units |
|---|---|---|
| Inches | 25.40 | millimeters (mm) |
| | 2.54 | centimeters (cm) |
| | 0.254 | decimeters (dm) |
| | 0.0254 | meters (m) |
| Feet | 0.3048 | meters (m) |
| Square Feet | 0.0929 | square meters ($m^2$) |
| Miles | 1.609 | kilometers (km) |
| Pounds | 453.60 | grams (g) |
| Ton | 0.9072 | tonne (t) |
| Acres | 0.4047 | hectares (ha) |
| | 0.004047 | square kilometers ($km^2$) |
| Square miles | 2.590 | square kilometers ($km^2$) |
| Cubic inches | 16.39 | cubic centimeters ($cm^3$) |
| Gallons | .003785 | cubic meters ($m^3$) |
| Acre-feet | .001233 | cubic hectometers ($hm^3$) |
| | 1233.00 | cubic meters ($m^3$) |
| Feet per mile | 0.1894 | meters per kilometer (m/km) |
| Inches per hour | 2.54 | centimeters per hour (cm/h) |
| Feet per day | .3048 | meters per day (m/d) |
| Pounds per square inch | 70.32 | grams per square centimeter ($g/cm^2$) |
| Atmospheres | 1033.27 | grams per square centimeter ($g/cm^2$) |
| Bars | 1019.78 | grams per square centimeter ($g/cm^2$) |
| Pounds per cubic foot | 0.01602 | grams per cubic centimeter ($g/cm^3$) |
| Pounds per acre | 1.1206 | kilograms per square hectometer ($kg/hm^2$) |
| Feet squared per day | 0.0929 | meters squared per day ($m^2/d$) |
| Cubic feet per second | 0.02832 | cubic meters per second ($m^3/s$) |
| Gallons per minute | 0.06309 | liters per second (l/s) |
| Cubic feet per second per square mile | 0.01093 | cubic meters per second per square kilometer [($m^3/s$)/$km^2$] |
| Cubic feet per day per square foot | 0.3048 | cubic meters per day per square meter ($m^3/d$)/$m^2$ |
| Pounds per square yard per hour | 0.5426 | kilograms per square meter per hour ($kg/m^2/h$) |
| Pounds per square foot per hour | 4.8827 | kilograms per square meter per hour ($kg/m^2/h$) |
| Btu per pound | 0.556 | kilogram calories per kilogram (kcal/kg) |
| Degree Fahrenheit | $Tc = \frac{Tf-32}{1.8}$ | degrees Celsius (°C) |

# APPENDIX B

# GEOLOGY

7-1337 (9-68)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 5

White Tail Butte Study Site
FEATURE Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming
HOLE NO. 76-101 LOCATION 1710' N. & 240' W. of SE Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV 4204± DIP (ANGLE FROM HORIZ) Vertical
BEGUN 6/9/76 FINISHED 6/25/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 333.5 BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED 183.8' 6/25/76 (4020.2) LOGGED BY Taucher LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole Started 6/9/76. Hx drive samples 0 to 10.0'. Hq wireline core 10.0 to 24.0'. Set 6" Cs to 5'. 100% drill water return. | | 76 | #1 0 | 13.0 | | | | | 10 | | | FT. UNION FORMATION - PALEOCENE* 0-13.0 SHALE AND CLAYEY SANDSTONE: Tan to gray-brown; oxidized; moist; alternating laminations and thin beds of plastic gray-brown shale (cuts easily with knife) & moderately plastic, uncemented, fine grain clayey sandstone (crushes easily between fingers); 60% of sample is shale; very slight HCl reaction; 1 to 3" core lengths. |
| | | 86 | | | | | | | | | | |
| | | 19 | | | | | | 4191.0 | 13.0 | | | |
| Hole at 24.0' 6/10/76. 6" Cs at 5.0'. W.L. at 18.9'. Hq wireline core 24.0 to 82.8'. 100% drill water return. | | 36 | #2 13.0 | 25.1 | | | | | 20 | | | 13.0-25.1 SHALE: Tan to gray-brown & highly oxidized 13.0 to 21.1'; dark gray to black carbonaceous shale with some oxidation 21.1 to 23.1'; medium gray to light gray, unoxidized shale 23.1 to 25.1'; moist; firm; moderately difficult trimming by knife; very plastic; appears bentonitic; air slacks; badly broken (1 to 2") 13.0 to 22.5'; 2 to 12" core lengths below 22.5'; 45° slickenside at 23.5'. |
| | | 100 | | | | | | 4178.9 | 25.1 | | | |
| | | | | | | | | 4176.9 | 27.1 | | | |
| Hole at 82.8' 6/11/76. 6" Cs at 5.0'. Hq wireline core 82.8 to 112.8'. | | 80 | | | | | | | 30 | | | |
| | | | #3 27.1 | 40.8 | | | | | | | | |
| 6/14/76. Unable to get to site because of rain & muddy roads. | | 96 | | | | | | | 40 | | | |
| | | | | | | | | 4163.2 | 40.8 | | | |
| Hole at 112.8' 6/15/76. 6" Cs at 5.0'. W.L. at 72.8'. Hq wireline core 112.8 to 152.8'. 100% drill water return. | | 95 | #4 40.8 | 45.8 | | | | 4158.2 | 45.8 | | | 25.1-27.1 COAL: Black; moist; badly broken along bedding planes; clay contamination; shaley 26.5 to 27.1'. |
| | | | #5 45.8 | 60.6 | | | | | 50 | | | 27.1-40.8 CLAYEY SILTSTONE WITH SILTY SHALE: Medium gray; moist; most of material is slight to moderately plastic clayey siltstone or very fine grain clayey sandstone which crushes easily between fingers; moderately plastic silty shale (trims easily by knife) 27.1 to 29.0, 32.0 to 32.7, 33.7 to 34.1 and 38.3 to 40.8'; core lengths 3 to 12". |
| | | 96 | | | | | | | | | | |
| Hole at 152.8' 6/16/76. 6" Cs at 5.0'. W.L. at 43.3'. Hq wireline core 152.8 to 193.0'. 100% drill water return to 188.0'. Lost all drill water at 188.0'. | | | | | | | | 4143.4 | 60.8 | | | 40.8-45.8 SILTY TO CLAYEY SANDSTONE WITH SILTY SHALE: Moist; alternating thin beds of non to slightly plastic, light gray, fine grain silty or clayey uncemented sandstone (crumbles easily between fingers) & moderately plastic, medium gray silty to sandy shale (trims easily with knife); slight acid reaction; core lengths ½ to 1". |
| | | 100 | | | | | | | 70 | | | |
| 6/17/76. Unable to get to site because of rain and muddy roads. | | 90 | #6 80.6 | 135.9 | | | | | 80 | | | 45.8-60.6 SILTY SANDSTONE: Light gray; moist; fine grain; trace of silt and clay; crumbles between fingers with no difficulty; moderate HCl reaction; generally thin-bedded or laminated 45.8 to 53.3'; bedding not generally apparent below 53.3'; angular to subrounded shale fragments imbedded in uncemented sandstone matrix (conglomerate) 56.4 to 57.0'; moderately cemented, fine grain calcareous sandstone (can't crush in fingers) 57.0 to 58.7'; 70° joint at 49.8'; core lengths 1 to 12". |
| | | 85 | | | | | | | | | | |
| | | 100 | | | | | | | 90 | | | |

CORE LOSS / CORE RECOVERY

EXPLANATION

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

White Tail Butte Study Site
FEATURE Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 1 OF 5 HOLE NO. 76-101

* Zone 0 to 13.0 ft. probably WASATCH FM. - EOCENE

7-1337 (9-68)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 5

White Tail Butte Study Site
FEATURE Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming
HOLE NO. 76-101 LOCATION 1710' N. & 240' W. of SE Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV 4204± DIP (ANGLE FROM HORIZ) Vertical
BEGUN 6/9/76 FINISHED 6/25/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 333.5 BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED 183.8' 6/25/76 (4020.2) LOGGED BY Taucher LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 193.0' 6/18/76. 6" Cs at 5.0'. Hole dry to 161.0'. Hq wireline core 193.0 to 204.0'. Mixed & injected heavy "revert" into hole but could not regain circulation. Could not get more water due to muddy conditions. Maintenance on equipment. | | 85 | | | | | | | 110 | | | 60.6-135.9 SHALE: Medium to dark gray; moist; firm to almost hard; approaching claystone; trims by knife with difficulty; very slight HCl reaction, especially in occasional silty stringers; air slacks in carbonaceous zones; 3 to 12" core lengths; bedding dips 0 to 5°. 60.6-67.8 - Shale with light gray sandstone laminations; clayey sandstone 66.8 to 67.8'; shale is about 70% of sample. 67.8-75.0 - Medium gray shale. 75.0-79.0 - Medium to dark gray shale, slightly carbonaceous. 79.0-82.8 - Dark gray to black carbonaceous shale, air slacks badly. 82.8-98.0 - Medium to dark gray shale, slightly carbonaceous; 45° slickenside at 87.0'; 2 opposing 45° joints at 97.8'. 98.0-135.9 - Medium gray silty shale, slightly carbonaceous, silty shale 101.0 to 104.8'. |
| | | 100 | | | | | | | 120 | | | |
| Hole at 204.0' 6/21/76. 6" Cs at 5.0'. Hq wireline core 204.0 to 244.0'. 100% drill water loss. | | 94 | | | | | | | 130 | | | |
| | | | | | | | | 4068.1 | 135.9 | | | |
| | | | | | | | | 4067.2 | 136.8 | | | |
| Hole at 244.0' 6/22/76. 6" Cs at 5.0'. W.L. at 183.1'. Washed out 6½' of core and cuttings. Hq wireline core 244.0 to 264.0'. 100% drill water loss. | | 98 | | | | | | | 140 | | | |
| | | 100 | #7 136.8 | 170.1 | | | | | 150 | | | 135.9-136.8 LIMESTONE: Dark gray; very hard; scratches with knife; unbroken; clay contamination. |
| 6/23/76. Unable to get to site because of rain and muddy roads. | | 100 | | | | | | | 160 | | | 136.8-170.1 SHALE: Medium to dark gray; moist; firm to almost hard; approaching claystone; trims by knife with difficulty; very slight HCl reaction; air slacks in carbonaceous zones; 3 to 12" core lengths. 136.8-144.2 - Medium gray shale. 144.2-146.6 - Brown to dark gray, carbonaceous shale. 146.6-147.7 - Badly broken coal. 147.7-149.2 - Light gray, laminated, uncemented, very fine grain sandstone; crumbles easily between fingers; ½ to 1" coal streaks at 148.3 & 149.1'. 149.2-150.0 - Laminated shale & silty sandstone. 150.0-169.7 - Medium to dark gray carbonaceous shale. 169.7-170.1 - Laminated silty sandstone and shale. |
| | | 100 | | | | | | | 170 | | | |
| | | 98 | | | | | | 4033.9 | 170.1 | | | |
| | | 100 | | | | | | | 180 | | | |
| | | 100 | | | | | | | 190 | | | |

ANDERSON E

170.1-207.4 COAL: Black; moist; shattered 182.8 to 197.5'; remaining core is broken in 1 to 3" lengths; scattered vertical fractures; occasional slickenside generally along bedding planes in top and bottom part of coal; logged after field samples taken; only about 40% of core remaining.

CORE LOSS / CORE RECOVERY

EXPLANATION

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

White Tail Butte Study Site
FEATURE Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 2 OF 5 HOLE NO. 76-101

7-1337 (9-68)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 5

White Tail Butte Study Site
FEATURE Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming
HOLE NO. 76-101 LOCATION 1710' N. & 240' W. of SE Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV 4204± DIP (ANGLE FROM HORIZ) Vertical
BEGUN 6/9/76 FINISHED 6/25/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 333.5 BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED 183.8' 6/25/76 (4020.2) LOGGED BY Taucher LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 264.0' 6/24/76. 4" Cs at 5.0'. W.L. at 183.6'. Washed out 40' of core in hole. Hq wireline core 264.0 to 303.6'. 100% drill water loss. | | 100 | | | | | | 3996.6 | 207.4 | | | 207.4-214.0 CARBONACEOUS SHALE: Dark gray to gray brown; moist; easy plastic; appears bentonitic; shattered by numerous irregular slickensides dipping at various angles; trims easily with knife; becoming highly carbonaceous (coaly shale) with ½ to 2" coal streaks 211.3 to 214.0'. |
| | | 100 | #8 207.4 | 214.0 | | | | | 210 | | | |
| | | | | | | | | 3990.0 | 214.0 | | | 214.0-240.2 COAL: Black; moist to wet; badly broken generally along bedding planes; dull; generally hard; logged after field samples taken; only about 40% of sample remaining. |
| Hole at 303.6' 6/25/76. 6" Cs at 5.0'. W.L. at 183.8'. Washed out 55' of core and cuttings. Hq wireline core 303.6 to 333.5'. Hole completed at 333.5'. Hole capped for geophysical logging. | | 100 | | | | | | | 220 | | | |
| | | 99 | | | | | | | 230 | | | 240.2-265.3 SHALE WITH SILTY SHALE AND SILTY SANDSTONE: Shale is medium gray, plastic & firm (trims by knife with difficulty); silty shale is light to medium gray & moderately plastic (trims easily with knife); silty sandstone is uncemented, light gray & fine grain (crumbles easily between fingers); moist; thin-bedded to laminated; core lengths 2 to 12" (average 8"). 240.2-241.2 - Plastic gray shale with silty sandstone 240.7 to 240.8'. 241.2-242.2 - Laminated light to medium gray shale & silty shale. 242.2-245.0 - Moderately soft, low plasticity silty shale. 245.0-246.0 - Plastic medium gray shale. 246.0-247.9 - Laminated silty, fine grain sandstone. 247.9-248.9 - Silty shale. 248.9-250.3 - Laminated silty shale & silty sandstone. 250.3-265.3 - Firm shale (approaching claystone) with laminated silty to sandy zones 252.5 to 253.0, 257.5 to 258.0, 260.5 to 261.0, and 263.5 to 265.3'. |
| | | | | | | | | | 240 | | | |
| 6/28/76. 6" Cs at 5.0'. W.L. at 184.5'. Cleaned out hole to 333.5' for logging probe. Pulled Cs. Set 3.5' of 5.0' casing. | | 99 | | | | | | 3963.8 | 240.2 | | | |
| | | 75 | #9 240.2 | 265.3 | | | | | 250 | | | |
| | | 80 | | | | | | | 260 | | | |
| | | | | | | | | 3938.7 | 265.3 | | | 265.3-268.1 CARBONACEOUS SHALE: Black; wet; firm; difficult trimming by knife; very plastic; air slacks; approaching shaley coal. |
| | | 85 | | | | | | 3935.9 | 268.1 | | | |
| | | | | | | | | | 270 | | | |
| | | 100 | | | | | | | 280 | | | 268.1-289.3 COAL: Black; wet; dull; broken along bedding planes; 2" black carbonaceous shale 288.7 to 288.9'; scattered vertical hairline fractures. |
| | | 100 | | | | | | 3914.7 | 289.3 | | | 289.3-290.4 SHALE: Dark gray; moist; carbonaceous; firm; trims by knife with difficulty; plastic; air slacks. |
| | | | | | | | | 3913.6 | 290.4 | | | |
| | | | | | | | | 3912.6 | 291.4 | | | 290.4-291.4 CLAYEY SANDSTONE: Mottled light & dark gray; moist; fine grain; moderately plastic when reworked; unbroken. |
| | | 94 | | | | | | 3905.7 | 298.3 | | | |

DIETZ F / CANYON G

CORE LOSS / CORE RECOVERY

EXPLANATION

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
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White Tail Butte Study Site
FEATURE Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 3 OF 5 HOLE NO. 76-101

## SOIL ANALYSES OF DRILL CORE

| Lab Number | Boring Number | Depth in Feet | Field Texture | Particle Size Analysis % Sand, dia. in mm 2.0-1.0 V.Co | 1.0-0.5 Co | 0.5-0.25 Med | 0.25-0.10 Fine | 0.10-0.05 V.Fine | % Silt | % 2μ Clay | Moisture Retention % Pressure in Bars 0.10 | 0.33 | 15. | Hyd Cond in/hrs 6 Hr | 24 Hr. | Sat Vol. ml | pH @ 25 $H_2O$ 1:5 | $CaCl_2$ | $EC_e \times 10^3$ @ 25°C | $EC_e \times 10^3$ @ 25°C | Saturation Extract Cations, me/l Ca | Mg | Na | K | Σ Cations | Anions, me/l $CO_3$ | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | SAR | SP | Total Extractable Cations me/100g Ca | Mg | Na | K | Exchangeable Cations me/100g Ca | Mg | Na | K | ESP | % Base Sat | Gyp me/100g | Gyp Req me/100g | CEC me/100g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6822 | 76-101 | 0.0-13.0 | | 23.2 | | | | | 43.9 | 32.9 | CL | 37.4 | 28.5 | 17.6 | 0.03 | 0.03 | 27 | 7.7 | 7.4 | 3.3 | 10. | 25.0 | 14.28 | 26.61 | 1.46 | 194.35 | 0.00 | 1.88 | 4.48 | 173.85 | 0.04 | 2.9 | 61.0 | 1.53 | 8.62 | 1.62 | 0.09 | | | | | 1.1 | | 18 | -14. | 18.9 |
| 3 | | 13.0-25.1 | | 1.8 | | | | | 45.4 | 52.8 | SiC | 47.2 | 40.5 | 26.5 | 0.06 | 0.08 | 31 | 5.8 | 5.6 | 2.1 | 6.0 | 24.25 | 69.65 | 6.78 | 2.15 | 102.83 | 0.00 | 3.84 | 0.64 | 89.53 | 0.45 | 1.0 | 68.7 | 1.67 | 4.78 | 0.47 | 0.15 | | | | | 0.5 | | 11. | -7.9 | 28.7 |
| 4 | | 27.1-40.8 | | 13.3 | | | | | 55.1 | 31.6 | SiCL | 42.6 | 34.8 | 19.7 | 0.07 | 0.07 | 28 | 7.9 | 7.6 | 0.50 | 2.6 | 10.08 | 14.14 | 5.17 | 1.64 | 31.03 | 0.48 | 6.40 | 0.00 | 22.55 | 0.02 | 1.5 | 68.6 | 0.69 | 0.97 | 0.35 | 0.11 | | | | | 0.4 | | 1.7 | -1.3 | 17.7 |
| 5 | | 40.8-45.8 | | 32.1 | | | | | 39.6 | 28.3 | CL | 40.5 | 32.0 | 17.0 | 0.08 | 0.09 | 25 | 8.0 | 7.6 | 0.46 | 2.6 | 12.48 | 11.02 | 6.35 | 1.65 | 31.50 | 0.24 | 6.32 | 0.56 | 23.53 | <0.02 | 1.9 | 62.8 | 0.78 | 0.69 | 0.40 | 0.10 | | | | | 0.8 | | 1.4 | -1.1 | 15.9 |
| 6 | | 45.8-60.6 | | 43.0 | | | | | 31.3 | 23.7 | L | 41.4 | 27.9 | 13.5 | 0.25 | 0.23 | 23 | 8.4 | 8.0 | 0.38 | 2.2 | 9.38 | 7.87 | 7.09 | 1.22 | 25.56 | 0.00 | 3.16 | 0.32 | 19.26 | <0.01 | 2.4 | 56.5 | 0.53 | 0.44 | 0.40 | 0.07 | | | | | 0.7 | | 0.8 | +0.3 | 21.8 |
| 7 | | 60.6-135.9 | | 2.5 | | | | | 61.9 | 35.6 | SiCL | 43.8 | 36.4 | 20.6 | 0.03 | 0.03 | 30 | 8.4 | 7.6 | 0.40 | 2.0 | 4.39 | 3.80 | 12.39 | 1.11 | 21.69 | 0.88 | 7.68 | 0.20 | 12.66 | <0.02 | 6.1 | 66.0 | 0.29 | 0.25 | 0.82 | 0.07 | | | | | 0.7 | | 0.7 | +0.5 | 19.5 |
| 8 | | 136.8-170.1 | | 1.9 | | | | | 59.3 | 38.8 | SiCL | 43.8 | 36.2 | 19.2 | 0.00 | 0.02 | 33 | 7.8 | 7.1 | 0.50 | 2.3 | 4.72 | 4.43 | 17.70 | 0.86 | 27.71 | 1.12 | 10.68 | 0.28 | 14.82 | <0.02 | 8.3 | 58.1 | 0.27 | 0.26 | 1.03 | 0.05 | | | | | 1.7 | | 1.7 | -0.5 | 23.7 |
| 9 | | 207.4-214.0 | | 1.9 | | | | | 16.9 | 81.2 | C | 40.7 | 36.9 | 21.9 | 0.00 | 0.00 | 80 | 7.3 | 6.9 | 0.36 | 1.5 | 2.03 | 1.81 | 12.35 | 0.57 | 16.76 | 0.32 | 2.40 | 0.24 | 13.28 | 0.02 | 8.9 | 70.1 | 0.14 | 0.13 | 0.88 | 0.04 | | | | | 2.3 | | 0.9 | +1.5 | 17.7 |
| 30 | | 240.2-265.3 | | 7.3 | | | | | 61.6 | 31.1 | SiCL | 34.1 | 27.5 | 14.7 | 0.00 | 0.00 | 36 | 7.5 | 7.1 | 0.40 | 2.6 | 6.99 | 6.78 | 14.22 | 1.45 | 29.44 | 0.32 | 4.16 | 0.28 | 24.01 | 0.02 | 5.4 | 52.0 | 0.36 | 0.35 | 0.74 | 0.03 | | | | | 0.9 | | 0.9 | 0.0 | 12.4 |
| 6831 | | 298.2-319.6 | | 6.9 | | | | | 51.0 | 42.1 | SiC | 39.1 | 31.3 | 19.8 | 0.00 | 0.00 | 31 | 8.0 | 6.9 | 0.40 | 2.8 | 6.74 | 5.34 | 16.34 | 1.41 | 29.75 | 0.00 | 3.68 | 0.44 | 22.69 | <0.02 | 6.6 | 56.0 | 0.38 | 0.30 | 0.74 | 0.08 | | | | | 1.2 | | 1.2 | +1.0 | 17.7 |

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH76-101

GEOLOGY G. J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH 977 SHEET 1 OF 2

1305-600-121

7-1337 (9-69) Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 5

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming

HOLE NO 76-101 LOCATION 1710' N. & 240' W. of SE Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV 4204± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6/9/76 FINISHED 6/25/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 333.5 BEARING --

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED 183.8' 6/25/76 (4020.2) LOGGED BY Taucher LOG REVIEWED BY

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 | #10 COMPOSITE SAMPLE | | | | | 3903.2 | 300.8 | | | 291.4-298.3 COAL: Black; wet; dull; broken; air slacks. |
| | | | | | | | | 3902.6 | 301.4 | | | |
| | | | | | | | | 3901.4 | 302.6 | | | |
| | | | | | | | | 3899.5 | 304.5 | | | 298.3-300.8 SHALE: Light gray; moist; firm; difficult trimming with knife; plastic; air slacks; black, carbonaceous shale with numerous slickensides 298.2 to 299.3'; sandy shale 300.3 to 300.8'; core lengths up to 3". |
| | | | 298.3 | 300.8 | | | | 3897.1 | 306.9 | | | |
| | | | 301.4 | 302.6 | | | | | | COOK ZONE | | |
| | 310 | | 302.6 | 304.5 | | | | | 310 | | | |
| | | | 306.9 | 319.6 | | | | | | | | |
| | | 85 | | | | | | | | | | 300.8-301.4 COAL: Black; broken; dull; air slacks. |
| | 320 | | | | | | | 3884.4 | 319.6 | | | |
| | | | | | | | | 3883.3 | 320.7 | | | 301.4-302.6 SHALE: Medium gray to black moist; firm; difficult trimming by knife; air slacks; cut by slickensides at random angles; black carbonaceous coaly shale 301.4 to 301.7 & 302.2 to 302.6'. |
| | | | | | | | | 3881.5 | 322.5 | | | |
| | | 100 | | | | | | | | | | |
| | 330 | | | | | | | | 330 | | | |
| | | | | | | | | 3872.3 | 331.7 | | | |
| | | | | | | | | 3870.5 | 333.5 | | | 302.6-304.5 SILTY SANDSTONE: Light to medium gray; moist; laminated; uncemented; fine grain; crumbles easily between fingers; core lengths 6". |
| | 340 | | | | | | | | 340 | | | 304.5-306.9 COAL: Black; wet; air slacks; dull; shaley 304.5 to 305.1'. |
| | 350 | | | | | | | | 350 | | | 306.9-319.6 SHALE WITH SILTY SHALE: Medium to light gray; moist; shale is firm & plastic (trims by knife with difficulty); silty shale is moderately firm & moderately plastic (trims easily with knife); core lengths up to 12" (average 8"). 306.9-312.5 - Medium gray plastic shale; irregular slickensides on 6 to 12" centers; badly broken 309.2 to 312.5'; carbonaceous 309.4 to 309.6 & 311.9 to 312.3'. 312.5-314.4 - Light gray silty shale; bedding not discernible. 314.4-316.4 - Laminated medium gray shale & clayey siltstone. 316.4-319.6 - Medium gray plastic shale; cut by numerous 45°± slickensides on 1 to 3" centers; air slacks. |
| | 360 | | | | | | | | 360 | | | |
| | 370 | | | | | | | | 370 | | | |
| | 380 | | | | | | | | 380 | | | 319.6-320.7 COAL: Black; wet; broken along bedding planes on ½ to 1" centers; air slacks. |
| | 390 | | | | | | | | 390 | | | 320.7-322.5 CARBONACEOUS SHALE: Black; wet; firm; difficult trimming by knife; approaching shaley coal; broken along bedding planes on ½ to 1" centers. 322.5-331.7 SILTY SHALE: Light gray; moist; firm; difficult trimming by |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Chain
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
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Outside dia. of casing (X-series) . E₃ = 1-13/16", A₃ = 2-1/4", B₃ = 2-7/8", N₃ = 3-1/2"
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FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 4 OF 5 HOLE NO 76-101

7-1337 (9-69) Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 5 OF 5

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming

HOLE NO 76-101 LOCATION 1710' N. & 240' W. of SE Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV 4204± DIP (ANGLE FROM HORIZ.) Vertical

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DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED 183.8' 6/25/76 (4020.2) LOGGED BY Taucher LOG REVIEWED BY

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | knife; moderately plastic to plastic; air slacks; slight HCl reaction in zones; very sandy 322.8 to 323.5'; core lengths 1 to 6". |
| | 10 | | | | | | | | 10 | | | 331.7-333.5 SILTY SANDSTONE: Light gray; moist; silty; fine grain; crumbles between fingers with difficulty; bedding not discernible; 3 to 6" core lengths. |
| | 20 | | | | | | | | 20 | | | |
| | 30 | | | | | | | | 30 | | | |
| | 40 | | | | | | | | 40 | | | |
| | 50 | | | | | | | | 50 | | | |
| | 60 | | | | | | | | 60 | | | |
| | 70 | | | | | | | | 70 | | | |
| | 80 | | | | | | | | 80 | | | |
| | 90 | | | | | | | | 90 | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

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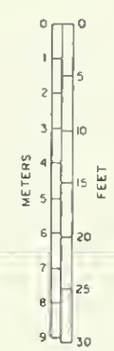
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . E₃ = 1-1/2", A₃ = 1-7/8", B₃ = 2-3/8", N₃ = 3"
Approx. size of core (X-series) . . E₃ = 7/8", A₃ = 1-1/8", B₃ = 1-5/8", N₃ = 2-1/8"
Outside dia. of casing (X-series) . E₃ = 1-13/16", A₃ = 2-1/4", B₃ = 2-7/8", N₃ = 3-1/2"
Inside dia. of casing (X-series) . E₃ = 1-1/2", A₃ = 1-29/32", B₃ = 2-3/8", N₃ = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 5 OF 5 HOLE NO 76-101




Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH 76-101

GEOLOGY G. J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1977 SHEET 2 OF 2 | 1305-600-122

F-1337 (5-69)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming
HOLE NO. 76-102 LOCATION 1140' S. & 2120' E. of NW Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4826± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 6/29/76 FINISHED 7/13/76 DEPTH OF OVERBURDEN --- TOTAL DEPTH 349.1 BEARING ---
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 221.3 7/13/76 (4004.7) LOGGED BY Taucher LOG REVIEWED BY

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boring Sample (Depth (Feet) From–To) | Suitability for Reconstructed Profile: Suitable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole started 6/29/76. Hx drive samples 0 to 10.0'. Hq wireline core 10.0 to 51.6'. 6" Ch set to 5.0', 50' drill water loss 22.0 to 26.5'. 100% return after using revert. | | 52 | | | | | | | | | FT. UNION FORMATION - PALEOCENE * 0-18.0 CLAYEY SILTSTONE: Tan & highly weathered to to 8.0 & 17.0 to 18.0'; light gray to tan & moderately oxidized 8.0 to 17.0'; dry to moist; soft; cuts easily with knife; low plasticity; shattered 0 to 8.0'; 1 to 3" core lengths below 8.0'; active HCl reaction; ½" coal at 9.0'. |
| | | 91 | #1 0–18.0 | | | | | | | | |
| | | 93 | | | | | | | | | |
| | | 15 | | | | | | | | | |
| | | 91 | | | | | 4208.0 | 18.0 | | | 18.0-41.0 SHALE: Tan to medium gray; oxidized with oxidation decreasing with depth to 40.0'; moist; firm; difficult trimming with knife; plastic; air slacks; 60° oxidized joint at 19.0, 20.0, 20.8 and 21.0'; limestone 22.3 to 22.5'; badly broken with some gypsum coated slickensides 24.0 to 28.0'; carbonaceous 24.8 to 25.3 & 31.8 to 32.8'; laminated light & medium gray calcareous shale 33.3 to 38.8'; black carbonaceous shale 40.0 to 41.0'; ½" gypsum filled bedding plane at 36.2'; core lengths up to 12". |
| Hole at 51.6' 6/30/76. 6" Ca set 5.0'. W.L. at 21.5'. Hq wireline core 51.6 to 101.5'. 20% drill water loss at 98.3' using revert. | | 100 | #2 18.0–41.0 | | | | | | | | |
| | | 100 | | | | | 4185.0 | C 41.0 | | | |
| | | | | | | | 4186.6 | 41.4 | | | |
| | | 98 | | | | | 4182.8 | 43.2 | | | 41.0-41.4 SHALE & COAL: Black; moist; plastic; alternating streaks of coal & carbonaceous shale; several gypsum lined bedding planes. |
| | | | #3 43.2–60.0 | | | | | | | | 41.4-43.2 COAL: Black; moist; broken. |
| | | 100 | | | | | | | | | 43.2-60.0 SHALE WITH SANDSTONE: Shale is medium gray; firm, plastic, & trims by knife with difficulty; sandstone is light gray, fine grain & slightly calcareous; moist; 60° slickenside at 43.5'; 50° joint at 44.8'; 50° joint at 50.4'; 60° joint at 53.9'; alternating shale & sandstone laminations 46.4 to 46.8'; laminated, uncemented, fine grain sandstone with ½" marcasite or pyrite nodules 48.3 to 48.8'; laminated silty sandstone 50.4 to 51.4'; laminated silty, uncemented sandstone 55.3 to 56.0'; calcareous cemented sandstone 56.0 to 57.5'; laminated shale & silty sandstone 59.5 to 60.0'; remaining material is shale; core lengths up to 12". |
| | | | | | | | 4166.0 | | | | |
| | | | #4 60.0–68.9 | | | | | | | | |
| | | 100 | | | | | 4157.1 | 68.9 | | | 60.0-68.9 SANDSTONE: Laminated light & dark gray; moist; uncemented; crumbles easily between fingers; very fine grain slight HCl reaction; plastic medium gray shale 63.4 to 65.6 & 66.6 to 67.8'; core lengths up to 12". |
| | | | #5 68.9–99.0 | | | | | | | | |
| | | 98 | | | | | | | | | |
| | | 99 | | | | | 4128.0 | 99.0 | | | 68.9-99.0 SHALE: Medium to dark gray; moist; firm; trims by knife with difficulty |

* Zone 0 to 18.0 ft. probably WASATCH FM. - EOCENE

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole ..... D = Diamond, H = Hayesaltite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Ca = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2" Ax = 1-7/8" Bx = 2-3/8" Nx = 3"
Approx. size of core (X-series) Ex = 1" Ax = 1-1/8" Bx = 1-5/8" Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16" Ax = 2-1/4" Bx = 2-7/8" Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2" Ax = 1-29/32" Bx = 2-3/8" Nx = 3"

FEATURE Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming SHEET 1 OF 4 HOLE NO 76-102

F-1337 (5-69)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming
HOLE NO. 76-102 LOCATION 1140' S. & 2120' E. of NW Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4826± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 6/29/76 FINISHED 7/13/76 DEPTH OF OVERBURDEN --- TOTAL DEPTH 349.1 BEARING ---
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 221.3 7/13/76 (4004.7) LOGGED BY Taucher LOG REVIEWED BY

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boring Sample (Depth (Feet) From–To) | Suitability for Reconstructed Profile: Suitable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 101.5' 7/1/76. 6" Ca at 5.0'. W.L. at 47.8'. Hq wireline core 101.5 to 150.7'. 100% water return. | | 99 | | | | | 4124.5 | 101.5 | | | air slacks; plastic; slightly calcareous; hard; medium gray limestone 72.2 to 73.0'; laminated shale & sandstone 68.9 to 70.0'; carbonaceous & dark gray to black 80.0 to 99.0'; 45° joint at 81.6'; 90° joint at 82.0 to 83.0, 83.5 to 84.0, & 94.0 to 96.0'; core lengths up to 12". |
| | | | #6 101.5–136.4 | | | | | | | | 99.0-101.5 SILTY SANDSTONE: Light gray; moist; uncemented; crumbles between fingers; fine grain; approaching siltstone in places; pulverized by drilling. |
| Hole at 150.7' 7/1/76. 6" Ca at 5.0'. W.L. at 52.6'. Hq wireline core 150.7 to 188.7'. 100% water return. Dropped 4.5' of core in hole on last run. | | 94 | | | | | | | | | 101.5-136.4 SILTY SHALE: Medium gray; moist; difficult trimming by knife; firm; bedding not readily discernible; plastic; air slacks; slight to moderate HCl reaction; numerous silty sand laminations 101.5 to 102.3'; 70° joint at 105.6'; claystone concretion 114.0 to 114.2'; very hard, dark gray limestone 123.8 to 125.2'; core lengths up to 12". |
| | | 98 | | | | | 4089.6 | 136.4 | | | |
| Hole at 188.7' 7/6/76. 6" Cs at 5.0'. W.L. at 88.6'. Washed out 10' of core in hole. Hq wireline core 188.7 to 223.0'. Total water loss at 217.0'. Mixed heavy revert & let set in hole over night. | | 100 | #7 136.4–182.8 | | | | | | | | 136.4-182.8 SHALE: Medium to dark gray; moist; firm; difficult trimming by knife; slight to moderate HCl reaction; plastic; air slacks; hard, round, limestone concretion 147.0 to 147.3'; 1" horizontal shear (slickensides) 164.9 to 165.0'; 65° joint at 164.7'; shale with silt laminations 150.0 to 156.0'; 1" limestone at 154.3'; dark gray & carbonaceous 178.0 to 182.8'; core lengths up to 12". |
| | | 100 | | | | | | | | | |
| | | 99 | | | | | | | | | |
| | | 100 | | | | | | | | | |
| | | 47 | | | | | | | | | |
| | | 100 | #8 182.8–211.9 | | | | | | | | 182.8-184.2 COAL: Black; moist; broken. |
| | | | | | | | 4043.2 | 182.8 | | | 184.2-188.7 SHALE: No core. |
| | | | | | | | 4041.8 | 184.2 | | | 188.7-211.9 SHALE: Dark gray to almost black; moist; firm; difficult trimming by knife; plastic; very weak HCl reaction in zones; carbonaceous; air slacks; approaching claystone in lower half; carbonaceous fine grain sandstone 211.2 to 211.6'; core lengths 1 to 12". |
| | | | | | | | 4037.3 | 188.7 | | | |
| | | | | | | | | | | | 211.9-248.5 COAL: Black; moist to wet; broken; driller reported pyrite cluster 242.5 to 242.9'; very little core visible for inspection as coal was sampled & bagged in field. |
| | | 60 | 211.9 | | | | | | | | 248.5-253.0 SHALE: Medium gray 248.5 to 251.0'; dark gray & carbonaceous below 251.0'; moist; firm to almost hard; difficult trimming by knife; cut by numerous horizontal to 45° slickensides on ¼ to 1" centers; core has metallic sheen and appears slightly metamorphosed; air slacks. |

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole ..... D = Diamond, H = Hayesaltite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Ca = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2" Ax = 1-7/8" Bx = 2-3/8" Nx = 3"
Approx. size of core (X-series) Ex = 1" Ax = 1-1/8" Bx = 1-5/8" Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16" Ax = 2-1/4" Bx = 2-7/8" Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2" Ax = 1-29/32" Bx = 2-3/8" Nx = 3"

FEATURE Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming SHEET 2 OF 4 HOLE NO 76-102

F-1337 (5-69)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming
HOLE NO. 76-102 LOCATION 1140' S. & 2120' E. of NW Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4826± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 6/29/76 FINISHED 7/13/76 DEPTH OF OVERBURDEN --- TOTAL DEPTH 349.1 BEARING ---
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 221.3 7/13/76 (4004.7) LOGGED BY Taucher LOG REVIEWED BY

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boring Sample (Depth (Feet) From–To) | Suitability for Reconstructed Profile: Suitable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 223.0' 7/7/76. 6" Ca at 5.0'. W.L. at 184.7'. Hq wireline core 223.0 to 263.0'. 100% water loss. | | 100 | | | | | | | | | 253.0-281.2 COAL: Black; moist; no core visible for inspection as coal was bagged & sampled in field. Driller reported pyrite cluster 268.2 to 268.5'. |
| | | 100 | | | | | 4014.1 | 211.9 | | | 281.2-295.3 SHALE WITH SILTY SANDSTONE: Shale is medium to dark gray, firm & difficult trimming by knife; sandstone is light grey, fine grain, silty to clayey & generally crushes easily between fingers; core lengths up to 12"; moist. 281.2-285.0 - Shale, carbonaceous 281.2 to 282.2'. 285.0-286.4 - Shale with about 30% silty sandstone stringers. 286.4-291.3 - Shale. 291.3-293.0 - Laminated silty to clayey sandstone with about 70% shale streaks. 293.0-295.3 - Shale; black & carbonaceous 294.3 to 295.3'. |
| Hole at 263.0' 7/8/76. 6" Ca at 5.0'. W.L. at 208.6'. Hq wireline core 263.0 to 302.5'. 100% drill water loss. Washed out 15.0' of core at start of shift. | | 100 | | | | | | | | | |
| | | 100 | | | | | | | | | |
| | | 100 | | | | | | | | | |
| | | 32 | #9 248.5–253.0 | | | | 3977.5 | 248.5 | | | 295.3-317.8 COAL: Black; moist; dull; very little coal was visible for inspection as coal was sampled & bagged in field. |
| | | 92 | | | | | 3973.0 | 253.0 | | | 317.8-319.1 SHALE: Medium gray grading to black with depth; moist; plastic; air slacks; shattered by numerous slickensides; coal streaks in bottom 1'. |
| | | | | | | | | | | | 319.1-320.3 COAL: Black; moist; dull; air slacks. |
| | | 100 | | | | | | | | | 320.3-327.0 SHALE: Dark gray to black & carbonaceous with thin coal streaks 320.3 to 322.0'; medium gray 322.0 to 327.0'; moist; firm; plastic; trims by knife with difficulty; air slacks; shattered by slickensides 322.7 to 323.7'; becoming sandy below 326.5'; core lengths up to 12". |
| | | 100 | | | | | | | | | 327.0-328.6 COAL: Black; moist to wet; dull broken. |
| | | 100 | | | | | 3944.8 | 281.2 | | | 328.6-332.7 SANDY SHALE: Medium gray; moist; moderately firm; trims easily with knife; moderately plastic; sand is very fine grain; ¼ to 3" core lengths. |
| | | 92 | #10 281.2–295.3 | | | | | | | | 332.7-335.0 COAL: Black; moist to wet; dull; broken. |
| | | 100 | | | | | 3930.7 | 295.3 | | | 335.0-342.7 SHALE: Medium gray to black; moist; firm; trims easily by knife; plastic; air slacks; dark gray to black carbonaceous shale with coal streaks 335.0 to 336.0'; slightly carbonaceous |

EXPLANATION

CORE LOSS
CORE RECOVERY

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Hole sealed ..... P = Packer, Ca = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2" Ax = 1-7/8" Bx = 2-3/8" Nx = 3"
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FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming SHEET 3 OF 4 HOLE NO 76-102

F-1337 (5-69)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming
HOLE NO. 76-102 LOCATION 1140' S. & 2120' E. of NW Corner, Sec. 32, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4826± DIP (ANGLE FROM HORIZ.) Vertical
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DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 221.3 7/13/76 (4004.7) LOGGED BY Taucher LOG REVIEWED BY

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boring Sample (Depth (Feet) From–To) | Suitability for Reconstructed Profile: Suitable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 302.5' 7/9/76. 6" Ca at 5.0'. W.L. at 222.3'. Washed out 50' of core in hole. Hq wireline core 302.5 to 332.7'. 100% drill water loss. | | 100 | | | | | | | | | 336.0 to 337.8'; black & highly carbonaceous 340.6 to 341.2 & 342.2 to 342.7'; silty sandstone 341.2 to 342.0'; scattered slickensides; core lengths up to 6". |
| Hole at 332.7' 7/12/76. 6" Ca at 5.0'. W.L. at 221.7'. Washed out 65' of core. Hq wireline core 332.7 to 349.1'. 100% drill water loss. Installed gravel & bentonite (4 to 1) from 349.1 to 252.0'. | | 75 | | | | | | | CANYON G | | 342.7-346.9 COAL: Black; moist to wet; dull; broken; shale contamination 342.7 to 343.3 & 345.0 to 346.9'. |
| | | 60 | #11 317.8–349.1 minus coal | 317.8 | 348.2 | | 3908.2 | 317.8 | | | 346.9-348.2 SILTY SHALE: Medium gray; moist; plastic; air slacks; shattered by drilling. |
| | | | | | | | 3906.9 | 319.1 | | | |
| | | | | | | | 3905.7 | 320.3 | | | 348.2-349.1 COAL: Black; wet; dull; broken. |
| Hole at 349.1' 7/13/76. 6" Ca at 5.0'. W.L. at 221.3'. Set 2" plastic pipe (bottom 38' perforated) to 252.0'. Filled hole with No. 8 grit sand from 252. to 210.0'. Hole from 210.0' to surface filled with sand & bentonite (4 to 1). Pulled 6" Ca & moved rig to DH 76-108. Hole completed. | | 100 | | | | | 3899.0 | 327.0 | | | |
| | | | | | | | 3897.4 | 328.6 | | | |
| | | | | | | | 3893.3 | 332.7 | | | |
| | | | | | | | 3891.0 | 335.0 | | | |
| | | | | | | | 3883.3 | 342.7 | | | |
| | | | | | | | 3879.1 | 346.9 | | | |
| | | | | | | | 3877.8 | 348.2 | | | |
| | | | | | | | 3876.9 | 349.1 | | | |

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole ..... D = Diamond, H = Hayesaltite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Ca = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2" Ax = 1-7/8" Bx = 2-3/8" Nx = 3"
Approx. size of core (X-series) Ex = 1" Ax = 1-1/8" Bx = 1-5/8" Nx = 2-1/8"
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FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EKRIA No. 13 STATE Wyoming SHEET 4 OF 4 HOLE NO 76-102

## SOIL ANALYSES OF DRILL CORE

| Lab Number | Boring Number | Depth in Feet | Field Texture | Particle Size Analysis: % Sand, dia. in mm (Ex-ce Vco, Ex-co Co, Ex-ma Med, Ex-fine Fine, Ex-vfine VFine) | % Silt | % Clay | Lab Test | Moisture Retention % Pressure in Bars 0.10 | 0.33 | 15 | Hyd Cond in/hrs 6 Hr | 24 Hr | Set Vol ml | pH @ 25 1:5 | $H_2O$ | $CaCl_2$ | $E_{ds}$ x $10^3$ @ 25°C | Saturation Extract: Cations, me/l Ca | Mg | Na | K | Σ Cations | Anions, me/l $CO_3$ | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | SAR | Total Extractable Cations me/100g Ca | Mg | Na | K | Exchangeable Cations me/100g Ca | Mg | Na | K | ESP | % Base Sat | Gyp me/100g | Gyp Req | CEC me/100g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6832 | 76-102 | 0.0-18.0 | | 1.9 | | 64.7 | 33.4 | SiCL | 36.6 | 30.6 | 14.2 | 0.06 | 0.05 | 35 | 8.2 | 7.8 | 1.0 | 5.0 | 13.12 | 36.92 | 21.87 | 0.68 | 72.59 | 0.00 | 1.72 | 5.06 | 41.00 | 1.85 | 4.4 | 77.0 | 1.02 | 2.86 | 1.69 | 0.03 | | | | | 3.0 | -3.0 | 10.2 | |
| 3 | | 18.0-41.0 | | 1.3 | | 47.2 | 51.5 | SiC | 43.2 | 34.3 | 22.8 | 0.04 | 0.03 | 33 | 4.7 | 7.4 | 1.5 | 5.8 | 24.10 | 44.82 | 19.11 | 1.36 | 90.30 | 0.00 | 3.68 | 1.49 | 18.06 | 1.13 | 3.3 | 70.8 | 1.76 | 3.17 | 1.36 | 0.10 | | | | | 5.6 | -4.8 | 25.2 | |
| 4 | | 45.2-60.0 | | 1.2 | | 65.1 | 33.7 | SiCL | 45.4 | 36.9 | 21.9 | 0.05 | 0.07 | 33 | 8.0 | 7.7 | 0.72 | 3.5 | 11.03 | 9.70 | 19.61 | 1.13 | 41.47 | 0.00 | 4.80 | 0.20 | 39.49 | 0.03 | 6.1 | 80.5 | 0.89 | 0.78 | 1.58 | 0.09 | | | | | 1.1 | 0.0 | 20.7 | |
| 5 | | 60.0-68.9 | | 30.7 | | 42.6 | 26.7 | L | 47.0 | 34.9 | 16.5 | 0.03 | 0.03 | 28 | 8.7 | 7.9 | 0.46 | 2.6 | 4.94 | 4.52 | 18.61 | 0.49 | 28.76 | 0.16 | 4.56 | 0.98 | 21.80 | <0.02 | 8.6 | 65.4 | 0.32 | 0.30 | 1.22 | 0.05 | | | | | 0.4 | +1.5 | 21.6 | |
| 6 | | 68.9-99.0 | | 3.1 | | 56.3 | 40.6 | SiC | 46.6 | 38.9 | 24.2 | 0.00 | 0.02 | 33 | 8.4 | 7.6 | 0.56 | 2.8 | 5.24 | 4.70 | 18.13 | 0.91 | 28.98 | 0.16 | 6.68 | 0.00 | 20.82 | <0.02 | 8.1 | 67.1 | 0.35 | 0.32 | 1.22 | 0.06 | | | | | 0.6 | +1.2 | 22.3 | |
| 7 | | 101.5-136.4 | | 0.6 | | 62.9 | 36.5 | SiCL | 44.7 | 36.9 | 24.1 | 0.00 | 0.02 | 35 | 8.6 | 7.7 | 0.40 | 1.4 | 1.87 | 3.17 | 11.96 | 0.69 | 17.69 | 0.48 | 7.20 | 0.18 | 9.06 | <0.02 | 7.5 | 74.9 | 0.14 | 0.24 | 0.90 | 0.05 | | | | | 0.3 | +2.0 | 18.5 | |
| 8 | | 136.4-182.8 | | 0.3 | | 60.9 | 38.8 | SiCL | 43.8 | 36.6 | 23.3 | 0.00 | 0.02 | 40 | 8.7 | 7.7 | 0.40 | 1.5 | 1.70 | 1.72 | 12.52 | 0.73 | 16.67 | 0.88 | 7.16 | 0.24 | 7.18 | <0.02 | 9.6 | 76.1 | 0.13 | 0.13 | 0.95 | 0.06 | | | | | 0.3 | +1.1 | 17.7 | |
| 9 | | 188.7-211.9 | | 4.2 | | 57.2 | 38.6 | SiCL | 42.9 | 35.8 | 21.8 | 0.00 | 0.01 | 32 | 7.2 | 6.7 | 0.40 | 2.5 | 4.94 | 5.16 | 17.13 | 1.06 | 28.29 | 0.00 | 7.00 | 0.42 | 16.55 | 0.05 | 7.6 | 57.5 | 0.26 | 0.28 | 0.92 | 0.06 | | | | | 0.7 | +1.3 | 25.7 | |
| 10 | | 248.5-253 | | 1.9 | | 11.4 | 86.7 | C | 46.2 | 38.9 | 25.4 | 0.00 | 0.00 | 150 | 7.7 | 7.1 | 0.36 | 1.5 | 2.07 | 1.90 | 11.76 | 0.56 | 16.51 | 0.00 | 2.72 | 0.36 | 11.81 | 0.03 | 8.5 | 75.8 | 0.16 | 0.14 | 0.91 | 0.04 | | | | | 0.6 | +1.5 | 20.6 | |
| 1 | | 18.2-Fill | | 7.6 | | 53.5 | 32.9 | SiCL | 33.9 | 27.7 | 15.7 | 0.00 | 0.00 | 55 | 7.6 | 6.8 | 0.24 | 1.6 | 2.31 | 2.26 | 11.00 | 0.78 | 16.35 | 0.00 | 4.48 | 0.26 | 10.72 | 0.04 | 7.3 | 30.0 | 0.12 | 0.11 | 0.55 | 0.04 | | | | | 0.6 | +0.7 | 11.0 | |
| 6842 | | 311.0-348.2 | | 2.6 | | 49.7 | 47.7 | SiC | 42.8 | 34.5 | 20.2 | 0.00 | 0.00 | 45 | 7.1 | 6.7 | 0.48 | 2.7 | 7.53 | 6.53 | 16.26 | 1.19 | 31.51 | 0.00 | 3.52 | 0.34 | 27.13 | 0.06 | 6.2 | 50.2 | 0.60 | 0.51 | 1.24 | 0.10 | | | | | 0.8 | +0.6 | 20.6 | |

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH 76-102

GEOLOGY G. J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1977
SHEET 1 OF 1

1305-600-123

7-1337 (8-63) Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 10

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO. 76-103 — LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV. Altimeter 4163± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 — FINISHED 10/6/76 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 710.2 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED ... — LOGGED BY Taucher to 233.0' — LOG REVIEWED BY ...

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Soils analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole started 7/29/76. Set up rig on site. Nx drive samples 0 to 9.0'. Hq wireline core 9.0 to 34.0'. Set 9.0' of 6" Cs. | | 100 | | | | | | | | | | FT. UNION FORMATION - PALEOCENE<br>0-30.8 SILTY SHALE: Tan & oxidized 0 to 24.5'; medium gray becoming dark gray & slightly carbonaceous with depth 24.5 to 28.0'; dark gray & carbonaceous 28.0 to 30.8'; dry 0 to 5.0'; damp to moist 5.0 to 30.8'; shattered by drilling & weathering 0 to 5.0'; broken in 1 to 3" core lengths 5.0 to 15.0'; 3 to 8" core lengths below 15.0'; moderately firm; trims easily with knife; moderately plastic, becoming plastic with depth; more silty in upper 24'; scattered gypsum crystals 0 to 10'; 80° joint 12.0 to 13.0 & 16.7 to 17.7'; 45° oxidized joint at 28.0'; calcareous 0 to 25.0'. |
| | | 88 | | | | | | | | | | |
| | | 100 | #1 0 | 24.5 | | | | | | | | |
| Hole at 34.0' 7/30/76. 6" Cs at 9.0'. Hq wireline core 34.0 to 63.0'. 100% water loss at 56.0'. | | 100 | | | | | | | | | | |
| | | 100 | #2 24.5 | 30.8 | | | | | | | | |
| Hole at 63.0' 8/2/76. 6" Cs at 9.0'. W.L. at 62.5'. Hq wireline core 63.0 to 83.0'. | | 100 | | | | | | 4132.2<br>4131.0 | 30.8<br>32.0 | | | 30.8-32.0 COAL: Black; moist; dull; broken in 1" pieces. |
| | | 95 | #3 32.0 | 50.5 | | | | | | | | 32.0-50.5 SHALE: Medium to dark gray; moist; firm; carbonaceous; plastic; trims by knife with some difficulty; bedding not readily discernible; very slight HCl reaction; air slacks; 45° joint at 37.0 & 45.9'; light gray, uncemented siltstone 32.0 to 33.5'; ½" coal at 33.5'; light gray, silty, fine grain, uncemented sandstone 50.0 to 50.5'; core lengths 2 to 24". |
| Hole at 83.0' 8/3/76. 6" Cs at 9.0'. W.L. at 62.3'. Hq wireline core 83.0 to 133.0'. | | 100 | | | | | | 4112.5 | 50.5 | | | 50.5-83.0 COAL: Black; moist; dull; broken; not visible for inspection as coal was sampled & bagged in field. |
| | | 100 | | | | | | | | | | 83.0-86.0 SILTSTONE: Light to medium gray; moist; uncemented; crumbles easily between fingers; sandy; slightly carbonaceous; core lengths 1 to 3". |
| | | 100 | | | | | | | | | | 86.0-86.5 COAL: Black; moist; dull; broken in 1" fragments. |
| | | 100 | | | | | | | | | | 86.5-89.8 SILTY SHALE: Medium to dark gray; moist; carbonaceous; moderately firm; air slacks; trims easily by knife; core lengths 3 to 8". |
| | | 94 | | | | | | 4080.0<br>4079.0<br>4076.5<br>4073.2<br>4071.5 | 83.0<br>84.0<br>86.5<br>89.8<br>91.5 | | | 89.8-91.5 COAL: Black; moist; dull; broken in 1" pieces. |
| | | 80 | #4 91.5 | 109.2 | | | | | | | | 91.5-109.2 SHALE: Dark gray & slightly carbonaceous 91.5 to 94.0'; light to medium gray 94.0 to 109.2'; moist; firm; difficult trimming by knife; plastic; air slacks; very hard, siliceous siltstone with carbonaceous inclusions 96.5 to 97.8'; 50° slickenside at 98.3, 104.4. |

ANDERSON

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Maystatline, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Hx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Hx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Hx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Hx = 3"

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 1 OF 10 — HOLE NO. 76-103

7-1337 (8-63) Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 10

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO. 76-103 — LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV. Altimeter 4163± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 — FINISHED 10/6/76 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 710.2 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED ... — LOGGED BY Taucher to 233.0' — LOG REVIEWED BY ...

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Soils analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 133.0' 8/4/76. 6" Cs at 9.0'. W.L. at 80.5'. Hq wireline core 133.0 to 194.0'. Used 4,000 gallons of water. | | 100 | | | | | | | | | | and 106.0'; 90° fresh joint at 106.5'; core lengths 3 to 18". |
| | | 86 | | | | | | 4053.8 | 109.2 | | | 109.2-133.0 SHALE WITH COAL: Medium to dark gray & carbonaceous; moist; firm; trims by knife with some difficulty; plastic; air slacks; bedding not readily discernible; medium gray & noncarbonaceous 119.0 to 120.8 & 129.5 to 132.0'; black and coaly 120.6 to 122.2 & 123.8 to 124.3'; coal 128.5 to 129.5'; scattered slickensides generally in more carbonaceous zones; bedding dips 5° at 119.8'; core lengths 1 to 8". |
| | | 82 | #5 109.2 minus | 133.0 coal | | | | | | | | |
| | | 78 | | | | | | 4030.0 | 133.0 | | | 133.0-153.0 SHALE, SILTY SHALE & COAL: Medium gray 133.0 to 145.5'; dark gray & carbonaceous 145.5 to 153.0' with broken coal 146.5 to 148.0'; moist; firm; difficult trimming by knife; plastic shale 133.0 to 140.0, 145.5 to 146.5 & 148.0 to 153.0'; silty shale cut by light gray siltstone laminations 140.0 to 145.5'; ½" pyrite nodule developed along bedding plane at 144.0'; air slacks below 148.0'; numerous slickensides 145.5 to 146.5'; core lengths 1 to 12". |
| Hole at 194.0' 8/5/76. 6" Cs at 9.0'. W.L. at 80.5'. Hq wireline core 194.0 to 224.0'. Washed core from hole below 130.0' at start of shift. Used 5000 gallons of water. Dropped part of core 214.0 to 224.0' in hole. Ground up 2' trying to recover. | | 96 | | | | | | | | | | |
| | | 94 | #6 133.0 minus | 153.0 coal | | | | | | | | |
| | | 100 | | | | | | 4010.0 | 153.0 | | | 153.0-172.2 COAL: Black; moist; dull; broken; not visible for inspection as coal was sampled & bagged in field. |
| | | 100 | | | | | | | | | | 172.2-172.5 SANDSTONE: Medium gray; moist; slightly carbonaceous; moderately cemented; fine grain; unable to crush between fingers. |
| | | 95 | | | | | | | | | | 172.5-177.0 SHALE: Medium gray; moist; firm; plastic; trims easily by knife; bedding not readily discernible; core lengths up to 8". |
| | | | #7 172.2 | 182.2 | | | | 3990.8<br>3990.5 | 172.2<br>172.5 | | | 177.0-179.2 SILTY SHALE & SANDSTONE: Alternating laminations & thin beds of soft, medium gray, silty shale & light gray, uncemented, fine grain sandstone. |
| | | 100 | | | | | | 3986.0<br>3983.8 | 177.0<br>179.2 | | | 179.2-182.2 SHALE: Dark gray; moist; plastic; firm; trims easily by knife; carbonaceous; air slacks; core lengths up to 6". |
| | | 100 | | | | | | 3980.8 | 182.2 | | | 182.2-203.0 COAL: Black; moist; dull; broken; not visible for inspection as coal was sampled & bagged in field. |
| | | 100 | | | | | | | | | | 203.0-209.1 SHALE: Medium to dark gray; moist; firm; trims by knife with some |

DIETZ — CANYON

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Maystatline, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Hx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Hx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Hx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Hx = 3"

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 2 OF 10 — HOLE NO. 76-103

7-1337 (8-63) Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 10

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO. 76-103 — LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV. Altimeter 4163± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 — FINISHED 10/6/76 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 710.2 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Taucher to 233.0' — LOGGED BY Hobbs (USCS) below 233.0' — LOG REVIEWED BY ...

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Soils analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 224.0' 8/9/76. 6" Cs at 9.0'. W.L. at 82.3'. Washed core to bottom of hole. Hq wireline core 224.0 to 233.0'. Innertube stuck in hole. | | 100 | | | | | | 3960.0<br>3957.0<br>3954.6 | 203.0<br>206.0<br>208.4 | | | difficulty; plastic; air slacks; carbonaceous; highly carbonaceous & brecciated 203.0 to 204.0'; slickensided along bedding planes below 204.0'; core lengths up to 3". |
| | | 100 | | | | | | 3949.2 | 213.8 | | | 206.0-208.4 SILTY SANDSTONE: Light gray; moist; compact; firm; can't crush between fingers; very fine grain; approaching sandy siltstone; bedding not readily discernible; core lengths 3 to 6". |
| Hole at 224.0' 8/10/76. 6" Cs at 9.0'. W.L. at 82.3'. Washed 120' of cave from hole. Recovered core from 224.0 to 233.0'. Hq wireline core 233.0 to 252.0'. | | 80 | #8 213.8 minus | 233.0 coal | | | | | | | | 208.4-213.8 COAL: Black; moist; dull; broken; not visible for inspection as coal was sampled & bagged in field. |
| | | 100 | | | | | | | | | | 213.8-233.0 SHALE WITH COAL: Black & carbonaceous 213.0 to 217.8'; light to medium gray 217.8 to 231.0 & 232.8 to 233.0'; broken coal 231.0 to 232.8'; moist; firm to 227.0'; moderately soft below 227.0'; plastic; air slacks; 45° slickensides at 215.3'; core lengths 1 to 6". |
| | | 24 | | | | | | 3930.0<br>3927.9<br>3920.3<br>3918.0 | 233.0<br>235.1<br>242.7<br>245.0 | | | 233.0-235.1 MUDSTONE: Medium to dark gray; carbonaceous stems, branches & fragments; grades into sandstone at 235.1'. |
| | | 95 | | | | | | | | | | 235.1-242.7 SANDSTONE: Gray; very fine grained; minor carbonaceous fragments; slickensides (contortion?) at 241.0'; bedded 241.7 to 242.7'. |
| | | 100 | | | | | | | | | | 242.7-245.0 MUDSTONE: Medium to dark gray with coal (stems & branches); lower part becoming black towards base. |
| Hole at 252.0' 8/11/76. 6" Cs at 9.0'. W.L. at 67.5'. Washed 100' of cave from hole. Hq wireline core 252.0 to 303.5'. Uncemented sandstone washed away 283.5 to 303.5'. | | 86 | | | | | | 3908.0<br>3905.6<br>3904.0<br>3900.8<br>3895.5<br>3894.0 | 255.<br>257.4<br>259.0<br>262.2<br>267.5<br>269.0 | | | 245.0-255.0 SANDSTONE: Gray; very fine grained; some bedding intermixed with nonbedded, very soft & crumbly sandstone; gray mudstone with imbedded stems & leaves 250.0 to 251.0'; mudstone 252.0 to 252.6'; 0.1' coal (tree branch) at 252.3'. |
| | | 92 | | | | | | | | | | 255.0-257.4 MUDSTONE: Gray; soft with minor carbonaceous material (stems & leaves); 45° fracture with slickensides 256.2 to 256.9'. |
| | | 97 | | | | | | 3879.5 | 283.5 | | | 257.4-259.0 SHALE: Black; very carbonaceous; almost coal. |
| | | 100 | | | | | | | | | | 259.0-259.6 SHALE: Brown; carbonaceous; contorted bedding. |
| | | 5 | | | | | | 3869.5 | 293.5 | | | 259.6-262.2 MUDSTONE: Gray; minor carbonaceous fragments. |

KOCH

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Maystatline, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Hx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Hx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Hx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Hx = 3"

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 3 OF 10 — HOLE NO. 76-103

7-1337 (8-63) Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 10

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO. 76-103 — LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV. Altimeter 4163± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 — FINISHED 10/6/76 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 710.2 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED ... — LOGGED BY Hobbs (USCS) — LOG REVIEWED BY ...

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Soils analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 303.5' 8/12/76. 6" Cs at 9.0'. W.L. at 67.5'. Washed out 130' of cave in hole. Hq wireline core 303.5 to 323.5'. Washed away uncemented sandstone. | | 0 | | | | | | | | | | 262.2-267.5 COAL: Medium hard; thin bands; blocky, uneven fracture 263.6 to 264.5'; brown, very hard, vertical filling (clay?) 263.9 to 265.0'; becomes more competent towards base; roof and floor contacts sharp. |
| 8/13/76 - Repaired water swivel. Not enough time to go in hole. Returned to duty station. | | 0 | | | | | | 3849.5 | 313.5 | | | 267.5-269.0 MUDSTONE: Gray; carbonaceous (roots) 267.5 to 268.1'. |
| Hole at 323.5' 8/16/76. 6" Cs at 9.0'. W.L. at 77.2'. Washing cave from hole. Used 1600 gallons of water. Did not reach bottom. | | 0 | | | | | | | | | | 269.0-283.5 SANDSTONE: Very fine grained; 1:0 silty streak at 271.2'; scattered carbonaceous (coal - 0.1' thick) fragments; crossbedded to 279.1'; fine grained 279.1 to 283.5' with scattered small pyrite nodules; very soft; core crushes between fingers; silty in parts |
| Hole at 323.5' 8/17/76. 6" Cs at 9.0'. W.L. at 77.0'. Washed 150' of cave from hole. Used 1600 gallons of water. Mixed and pumped 2 pits of drill mud in hole. Pulled Hq rods. Set Nx Cs to 330.0' Hq wireline core 323.5 to 330.0'. Driller reported sandstone washing away. | | 100 | | | | | | 3839.5 | 323.5 | | | 283.5-293.5 Only recovered 0.5' of mudstone; drill reported SANDSTONE washed away by drilling; probably similar to zone 269.0 to 283.5'. |
| | | 100 | | | | | | 3821.6 | 341.4 | | | 293.5-313.5 No core recovered; driller reported SANDSTONE (same as above). |
| | | 100 | | | | | | 3812.1 | 350.9 | | | 313.5-323.5 Recovered 3.0' of SANDSTONE; gray; very fine grained; some silty streaks. |
| Hole at 330.0' 8/18/76. 6" Cs at 9.0'. Nx Cs at 330.0'. W.L. at 102.8'. Washed out hole. Nx core 330.0 to 346.7'. | | 95 | | | | | | | | | | 323.5-330.0 Driller reported SANDSTONE; no core recovery. |
| Hole at 346.7' 8/19/76. 6" Cs at 9.0'. Nx Cs at 330.0'. Unable to determine W.L. Nx core 346.7 to 402.2'. Losing 70% of drill water. Used 2400 gallons of water. Sand washed away 389.2 to 402.2'. | | 100 | | | | | | | | | | 330.0-341.4 COAL: Dull & bright bands; minor pyrite on bedding; badly broken in upper 1.5'; balance of core in hard; silty shale 334.6 to 335.0'; silty coal 338.8 to 339.2'; bottom 0.1' of coal is flakey; floor contact. |
| | | 100 | | | | | | | | | | 341.4-350.0 MUDSTONE: Gray; soft; crumbly; minor carbonaceous material; becomes brownish at 343.8'; 0.2' of coal at 344.2'; interbedded coal & brown shale 345.0 to 345.4'; several 45° fractures with slickensides 348.2 to 350.0'. |
| | | 100 | | | | | | | | | | 350.0-350.9 SILTSTONE: Gray with minor, very fine grained sandstone; 45° fracture (slickenside) at 350.0'. |
| | | 100 | | | | | | | | | | 350.9-351.6 MUDSTONE: Very soft to mud-like in top 1.0'. |
| | | 0 | | | | | | | | | | 351.6-411.7 SANDSTONE: Very fine grained; massive; vertical coaly streak (roots) 351.6 to 355.6'; grades into gray mudstone 355.6 to 356.4'; even crossbedded |

UNNAMED

EXPLANATION

CORE LOSS / CORE RECOVERY

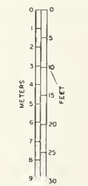
Type of hole ..... D = Diamond, H = Maystatline, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Hx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Hx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Hx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Hx = 3"

FEATURE White Tail Butte Study Site, Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 4 OF 10 — HOLE NO. 76-103

## SOIL ANALYSES OF DRILL CORE

| Lab Number | Boring Number | Depth in Feet | Field Texture | Particle Size Analysis: % Sand, dia. in mm: 2.0-1.0 V.Co | 1.0-0.5 Co | 0.5-0.25 Med | 0.25-0.10 Fine | 0.10-0.05 V.Fine | % Silt | % 2μ Clay | Lab Text | Moisture Retention % Pressure in Bars: 0.10 | 0.33 | 15. | 6 Hr. | 24 Hr. | Hyd Cond in/hrs. | Sat. Vol. ml | pH @ 25 °C: H2O 1:5 | CaCO3 | Ec x10³ @ 25°C | Cations, me/l: Ca | Mg | Na | K | Σ Cations | Saturation Extract: Anions, me/l: CO3 | HCO3 | Cl | SO4 | NO3 | SAR | SP | me/100g: Ca | Mg | Na | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6843 | 76-103 | 00-24.5 | | 17 | | | | | 60.6 | 37.7 | SiCL | 43.7 | 36.1 | 20.3 | 0.08 | 0.08 | 81 | 7.9 | 7.6 | 1.6 | 5.0 | 25.30 | 37.58 | 12.30 | 1.14 | 76.32 | 0.00 | 1.32 | 1.58 | 68.50 | 0.24 | 2.2 | 67.6 | 1.71 | 2.54 | 0.83 | 0.08 |
| 4 | | 245-308 | | 04 | | | | | 61.4 | 38.2 | SiCL | 46.3 | 38.5 | 22.9 | 0.07 | 0.09 | 32 | 7.5 | 7.1 | 0.52 | 2.6 | 10.18 | 12.01 | 6.70 | 1.40 | 30.29 | 0.00 | 5.08 | 0.80 | 22.07 | 0.15 | 2.0 | 64.3 | 0.65 | 0.77 | 0.43 | 0.09 |
| 5 | | 320-505 | | 29 | | | | | 57.1 | 40.0 | SiCL | 37.9 | 38.3 | 22.8 | 0.00 | 0.02 | 33 | 7.2 | 6.8 | 0.36 | 2.0 | 7.78 | 7.33 | 8.87 | 1.13 | 25.11 | 0.00 | 5.20 | 0.32 | 16.46 | 0.07 | 3.2 | 62.0 | 0.48 | 0.45 | 0.55 | 0.07 |
| 6 | | 915-1092 | | 14 | | | | | 38.9 | 59.7 | C | 40.5 | 34.1 | 19.4 | 0.00 | 0.00 | 90 | 8.2 | 7.6 | 0.38 | 1.9 | 4.17 | 3.26 | 10.96 | 0.82 | 19.21 | 0.00 | 2.71 | 0.32 | 16.28 | 0.02 | 5.7 | 73.9 | 0.31 | 0.24 | 0.81 | 0.06 |
| 7 | | 1092-1330 | | 22 | | | | | 27.6 | 70.2 | C | 45.3 | 38.7 | 22.1 | 0.00 | 0.00 | 70 | 7.5 | 6.6 | 0.52 | 2.6 | 6.04 | 4.98 | 15.22 | 0.91 | 27.15 | 0.00 | 2.52 | 0.00 | 23.84 | 0.04 | 6.5 | 84.7 | 0.51 | 0.42 | 1.29 | 0.08 |
| 8 | | 1330-1530 | | 24 | | | | | 48.0 | 49.6 | SiC | 38.6 | 32.1 | 18.6 | 0.00 | 0.00 | 90 | 7.6 | 6.7 | 0.50 | 2.3 | 5.69 | 4.70 | 14.35 | 0.90 | 25.64 | 0.00 | 2.52 | 0.26 | 22.44 | 0.04 | 6.3 | 64.0 | 0.36 | 0.30 | 0.92 | 0.06 |
| 9 | | 1722-1812 | | 11.8 | | | | | 51.8 | 36.4 | SiCL | 32.7 | 27.2 | 14.2 | 0.00 | 0.00 | 110 | 7.7 | 6.7 | 0.20 | 1.2 | 1.81 | 1.45 | 10.52 | 0.53 | 14.31 | 0.00 | 3.00 | 0.52 | 10.10 | 0.03 | 8.2 | 47.0 | 0.09 | 0.07 | 0.49 | 0.02 |
| 6830 | | 2136-2330 | | 3.7 | | | | | 41.6 | 54.7 | SiC | 43.1 | 37.7 | 22.1 | 0.00 | 0.00 | 35 | 8.1 | 6.8 | 0.30 | 1.4 | 1.48 | 1.18 | 10.71 | 0.55 | 14.12 | 0.00 | 2.76 | 0.44 | 5.00 | 0.02 | 9.5 | 65.5 | 0.10 | 0.08 | 0.70 | 0.04 |

| Lab Number | Total Extractable Cations me/100g: Ca | Mg | Na | K | Exchangeable Cations me/100g: Ca | Mg | Na | K | ESP | % Base Sat | Gyp me/100g | Gyp Req me/100g | CEC me/100g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6843 | 1.04 | 0.41 | | | 0.21 | 0.33 | 1.1 | | 6.2 | -5.3 | 18.3 | | |
| 4 | 0.70 | 0.42 | | | 0.27 | 0.33 | 1.2 | | 1.6 | -1.1 | 23.1 | | |
| 5 | 1.04 | 0.17 | | | 0.49 | 0.10 | 1.8 | | 0.9 | -0.1 | 26.6 | | |
| 6 | 1.65 | 0.51 | | | 0.84 | 0.51 | 4.9 | | 1.7 | -0.4 | 17.2 | | |
| 7 | 2.26 | 0.59 | | | 0.97 | 0.51 | 4.3 | | 1.7 | 0.0 | 22.3 | | |
| 8 | 1.74 | 0.43 | | | 0.82 | 0.37 | 4.6 | | 1.0 | +0.4 | 18.0 | | |
| 9 | 1.13 | 0.26 | | | 0.64 | 0.24 | 5.0 | | 1.1 | 0.0 | 12.9 | | |
| 6830 | 2.08 | 0.71 | 6.5 | | 0.9 | +2.3 | 32.0 | | | | | | |




Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH 76-103

GEOLOGY G. J. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH, 1977 — SHEET 1 OF 3

1305-600-124

7-1337 (8-62)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 5 OF 10

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming
HOLE NO. 76-103 LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4163± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 FINISHED 10/4/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 710.2 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Hobbs (USGS) to 411.7', Haddock (USGS) below LOGGED BY Haddock (USGS) LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | % CORE RECOVERY | BOILD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVA. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 402.2' 8/20/76. 6" Cs at 9.0'. Nx Cs at 330.0'. Nx wireline core 402.2 to 422.2. 75% drill water return. Washed away part of cave. Returned to duty station. | | 0 | | | | | | | | | | with carbonaceous material & sandstone 361.4 to 368.9'; very soft & crumbly 368.9 to 378.2'; crossbedded with heavy carbonaceous material 372.4 to 373.2 & 378.8 to 380.3'; becomes very light gray to white 406.2 to 410.3'; gray, fine grained, carbonaceous, crossbedded sandstone 410.3 to 411.7'. |
| 8/23/76.- Returned from duty station. Greased rig & hauled water. | | 95 | | | | | | 3751.3 | 411.7 | | | 411.7-412.9 MUDSTONE: Dark gray with interbedded sandstone. |
| Hole at 422.2' 8/24/76. 6" Cs at 9.0'. Nx Cs at 330.0. Nx wireline core 422.2 to 450.0. Stuck tools in hole because of caving sand. Washed hole with 800 gallons of water (1½ hrs.) to free tools. Mixed & pumped into hole 2 pits of revert. Uncemented sandstone washing away during coring. | | 20 | | | | | | 3949.0 | 414.0 | | | 412.9-413.3 MUDSTONE: More dense than 411.7 to 412.9'; less interbedded sandstone; some carbonaceous material. |
| | | 70 | | | | | | 3740.8 | 422.2 | | | 413.3-414.0 MUDSTONE: Same as 411.7 to 412.9'; increasing sandstone. |
| | | 56 | | | | | | | | | | 414.0-422.2 No core recovery. Driller reported SANDSTONE WITH SHALE SEAMS. |
| | | 14 | | | | | | 3722.0 | 441.0 | | | 422.2-422.7 SANDSTONE: Light gray; fine grained; contains clumps of dark gray mudstone. |
| | | 55 | | | | | | 3718.5 | 444.5 | | | 422.7-423.6 MUDSTONE: Dark gray; crossbedded with abundant carbonaceous material; thin, interbedded sandstone at 423.3'. |
| | | 100 | | | | | | 3709.0 | 454.0 | | | 423.6-424.9 SANDSTONE: Light gray; fine grained with near vertical interbeds of mudstone & carbonaceous material ("clay veins"). |
| Hole at 450.0' 8/25/76. 6" Cs at 9.0'. Nx Cs at 330.0'. Washed out cave in hole (½ shift). Pulled rods & changed bit. Nx core 450.0 to 472.0. | | 88 | | | | | | 3707.5 | 455.5 | | | 424.9-426.4 SANDSTONE: Light gray; fine grained with crossbedded carbonaceous material. |
| | | 100 | | | | | | 3701.8 | 461.2 | | | 426.4-428.2 SANDSTONE: Same as above except more massive; carbonaceous material very abundant. |
| Hole at 472.0' 8/26/76. 6" Cs at 9.0'. Nx Cs at 330.0'. Washed cave from hole (3 hrs.). Hole caving badly from 340 to 370'. Nx core 472.0 to 504.2'. | | 100 | | | | | | 3698.3 | 464.7 | | | 428.2-428.8 SANDSTONE: Same as zone 424.9 to 426.4'; no carbonaceous material. |
| | | 100 | | | | | | 3695.2 | 467.8 | | | 428.8-432.2 No core recovery. Driller reported SANDSTONE. |
| | | 100 | | | | | | 3684.4 | 478.6 | WALL J | | 432.2-436.8 SANDSTONE: Pockets of mudstone at 432.2, 433.1 & 435.3'. |
| | | 80 | | | | | | 3680.5 | 482.5 | | | 436.8-441.0 No core recovery. Driller reported SANDSTONE. |
| Hole at 504.2' 8/27/76. 6" Cs at 9.0'. Nx Cs at 330.0'. Pulled rods, changed bit & put 320' of rods back in hole. Hauled water. | | 100 | | | | | | 3675.1 | 487.9 | | | 441.0-441.5 MUDSTONE: Light gray; very hard; near conchoidal fracture. |
| | | | | | | | | 3667.4 | 495.6 | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (R-series) Ex = 1:1.2", As = 1:1.7/8", Bx = 2:3/8", Hx = 3"
Approx. size of core (R-series) Ex = 7/8", As = 1:1/8", Bx = 1:5/8", Hx = 2:1/8"
Outside dia. of casing (R-series) Ex = 1:1/16", As = 2:1/4", Bx = 2:7/8", Hx = 3:1/2"
Inside dia. of casing (R-series) Ex = 1:1/2", As = 1:29/32", Bx = 2:3/8", Hx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 5 OF 10 HOLE HO 76-103

7-1337 (8-62)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 6 OF 10

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming
HOLE NO. 76-103 LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4163± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 FINISHED 10/4/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 710.2 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Haddock (USGS) to 499.7' LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | % CORE RECOVERY | BOILD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVA. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 504.2' 8/30/76. 6" Cs at 9.0'. Nx Cs at 330.0'. Returned from duty station. Pulled drill rods. | | 100 | | | | | | 3660.6 | 502.6 | | | 441.5-444.5 No core recovery. Driller reported SANDSTONE. |
| | | 100 | | | | | | 3658.1 | 504.9 | | | 444.5-444.9 MUDSTONE: Dark gray. |
| Hole at 504.2' 8/31/76. 6" Cs at 9.0'. Nx Cs at 330.0'. Hammered Nx Cs back 70'. Very hard to pull. | | 50 | | | | | | 3655.8 | 507.2 | | | 444.9-447.5 SANDSTONE: Light gray to light tan; 80% medium grained; 20% fine grained; carbonaceous material 446.4 to 446.6'. |
| | | 69 | | | | | | 3651.0 | 512.0 | | | 447.5-450.0 No core recovery. Driller reported SANDSTONE. |
| Hole at 504.2' 9/1/76. 6" Cs at 9.0'. Nx Cs at 260.0'. Pulled remaining Nx Cs. Reamed hole to 350.0'. Used 3200 gallons of water. | | 22 | | | | | | 3635.3 | 527.7 | | | 450.0-454.0 SANDSTONE: Same as zone 444.9 to 447.5'; grading into fine grained, carbonaceous material at 453.0. |
| | | 64 | | | | | | 3631.5 | 531.5 | | | 454.0-454.5 SILTSTONE: Light gray; grades into mudstone. |
| Hole at 504.2' 9/2/76. 6" Cs at 9.0'. Reamed hole to 502.0'. Mixed & pumped heavy drill mud into hole. Used 5600 gallons of water. | | 85 | | | | | | 3628.4 | 534.6 | | | 454.5-455.5 MUDSTONE: Dark gray; carbonaceous material at 455.4'. |
| | | 0 | | | | | | 3626.4 | 536.6 | | | 455.5-456.1 SANDSTONE: Light gray; very fine to fine grain; upper contact with mudstone is sharp; lower contact is gradational. |
| Hole at 504.2' 9/3/76. 6" Cs at 9.0'. Worked on equipment. Returned to duty station. | | 44 | | | | | | 3621.0 | 542.0 | | | 456.1-457.6 SILTSTONE: Light gray; interbedded light gray sandstone & carbonaceous material; abundant carbonaceous material 456.6 to 457.6'; grading into sandstone with depth. |
| Hole at 504.2' 9/7/76. 6" Cs at 9.0'. Picked up new drill helpers. Unable to work at site. | | 100 | | | | | | 3606.0 | 557.0 | | | 457.6-458.3 SANDSTONE: Light gray; very fine grained; siltstone pockets 457.6 to 457.8'. |
| | | 100 | | | | | | 3600.0 | 563.0 | | | 458.3-459.6 SILTSTONE: Dark gray with interbedded, very fine grained sandstone. |
| Hole at 504.2' 9/8/76. 6" Cs at 9.0'. Washed out hole & pulled rods. Set Nx Cs to 502.0'. Used 2400 gallons of water. | | 100 | | | | | | 3597.5 | 565.5 | PRINNEE K | | 459.6-461.2 MUDSTONE: Dark gray with abundant carbonaceous material. |
| | | 100 | | | | | | | | | | 461.2-462.0 No core recovery. Driller reported SHALE. |
| Hole at 504.2' 9/9/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Nx core 504.2 to 522.0'. Losing 80% of water. Washed hole with "W" rods prior to coring. | | 100 | | | | | | 3573.7 | 589.3 | | | 462.0-463.9 MUDSTONE: Slickensided surfaces; chunks of coal & abundant carbonaceous material 462.3 to 463.9'. |
| | | 92 | | | | | | 3572.0 | 591.0 | | | 463.9-464.7 MUDSTONE: Interbedded with light gray, very fine grained sandstone; much less carbonaceous material. |
| Sand washed away while coring. | | | | | | | | 3570.2 | 592.8 | | | 464.7-467.8 SANDSTONE: Tan; fine grained; some interbeds of carbonaceous material 467.0 to 467.8'. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (R-series) Ex = 1:1.2", As = 1:1.7/8", Bx = 2:3/8", Hx = 3"
Approx. size of core (R-series) Ex = 7/8", As = 1:1/8", Bx = 1:5/8", Hx = 2:1/8"
Outside dia. of casing (R-series) Ex = 1:1/16", As = 2:1/4", Bx = 2:7/8", Hx = 3:1/2"
Inside dia. of casing (R-series) Ex = 1:1/2", As = 1:29/32", Bx = 2:3/8", Hx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 6 OF 10 HOLE HO 76-103

7-1337 (8-62)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 7 OF 10

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming
HOLE NO. 76-103 LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4163± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 FINISHED 10/4/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 710.2 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Haddock (USGS) to 499.7' LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | % CORE RECOVERY | BOILD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVA. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 522.0' 9/10/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Pulled rods & changed bit. Nx core 522.0 to 542.0. Losing 80% of drill water. Some sand washing away. | | 45 | | | | | | 3562.6 | 600.4 | | | 467.8-468.0 COAL: Bright banded; hard; appears to have been cut out by overlying sandstone. |
| | | 20 | | | | | | 3554.0 | 609.0 | | | 468.0-468.3 SANDSTONE: Gray; very fine grained; abundant carbonaceous material & pyrite. |
| Hole at 542.0' 9/13/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Nx core 542.0 to 571.0'. Uncemented sand washing away during drilling. 80% water loss. | | 3 | | | | | | 3544.0 | 619.0 | | | 468.3-478.6 COAL: Badly broken by drilling; bright & dull bands. |
| | | 0 | | | | | | 3534.0 | 629.0 | | | 478.6-482.5 MUDSTONE: Light gray; abundant carbonaceous material; very soft (clay-like); light gray below 482.0'. |
| Hole at 571.0' 9/14/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Nx core 571.0 to 659.0'. Uncemented sand washing away while coring. 100% water loss at 575.0'. Used 4000 gallons of water. | | 20 | | | | | | 3516.0 | 647.0 | | | 482.5-482.7 SANDSTONE: Light gray, very fine grained. |
| | | 9 | | | | | | | | | | 482.7-483.4 SILTSTONE: Light gray with interbedded very fine grained sandstone. |
| Hole at 659.0' 9/15/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Nx core 659.0 to 680.0'. Pulled rods to change bit. Core blocking below 668.0'. Used 3200 gallons of water. | | 64 | | | | | | 3504.0 | 659.0 | | | 483.4-485.6 MUDSTONE: Dark gray; locally silty with carbonaceous material; very silty in lower 2'. |
| | | 90 | | | | | | 3501.0 | 662.0 | | | 485.6-486.7 SILTSTONE: Light gray; calcareous; very hard; massive. |
| Hole at 680.0' 9/16/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Nx core 680.0 to 710.2'. Left rods in hole while USGS logged (geophysical) hole. Pulled rods. | | 100 | | | | | | 3496.0 | 667.0 | | | 486.7-487.9 SANDSTONE: Very fine grained; soft, locally silty. |
| | | 100 | | | | | | | | | | 487.9-490.2 MUDSTONE: Dark gray; interbedded siltstone; sharp upper contact with sandstone. |
| | | 81 | | | | | | 3479.3 | 683.7 | CACHE L | | 490.2-495.6 MUDSTONE: Dark gray & similar to 487.9 to 490.2'; becoming harder & mottled in appearance below 492.7'; some carbonaceous material. |
| | | 54 | | | | | | | | | | 495.6-496.6 SANDSTONE: Light gray; hard; very fine grain. |
| 9/17/76 - Returned to duty station. | | 90 | | | | | | | | | | 496.6-499.3 MUDSTONE: Dark gray with interbedded sandstone & carbonaceous material. |
| 9/17/76 - Broke down "W" rods. Moved rods & equipment to new site. | | 90 | | | | | | 3464.5 | 698.5 | | | 499.3-499.7 SILTSTONE: Light gray, very hard. |
| | | | | | | | | | | | | 499.7-502.4 SILTSTONE: Light gray; hard; some very fine sand grains. |
| | | | | | | | | | | | | 502.4-504.9 LIMESTONE: Gray; very hard; sharp upper contact; irregular, sharp lower contact, dark; sand-sized grains; very fine grained; irregular bedding surfaces; irregular finely divided carbonaceous material in rare places; vugular porosity on outside core surface. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (R-series) Ex = 1:1.2", As = 1:1.7/8", Bx = 2:3/8", Hx = 3"
Approx. size of core (R-series) Ex = 7/8", As = 1:1/8", Bx = 1:5/8", Hx = 2:1/8"
Outside dia. of casing (R-series) Ex = 1:1/16", As = 2:1/4", Bx = 2:7/8", Hx = 3:1/2"
Inside dia. of casing (R-series) Ex = 1:1/2", As = 1:29/32", Bx = 2:3/8", Hx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 7 OF 10 HOLE HO 76-103

7-1337 (8-62)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 8 OF 10

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming
HOLE NO 76-103 LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W. Altimeter GROUND ELEV. 4163± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/29/76 FINISHED 10/4/76 DEPTH OF OVERBURDEN -- TOTAL DEPTH 710.2 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Cooley (USGS) below LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | % CORE RECOVERY | BOILD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVA. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 710.2' 9/21/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Washed out hole. Hole caved at 620.0'. | | 70 | | | | | | 3460.2 | 702.8 | | | 504.9-507.2 SANDSTONE: Gray; very fine grained; soft. |
| Hole at 710.2' 9/22/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Washed out hole. Hole caving 670.0 to 680.0'. Stuck tools. Drove tools out with big hammer. Mixed & pumped 6 pits of revert in hole. | | | | | | | | 3452.8 | 710.2 | | | 507.2-508.0 SILTSTONE: Light gray; hard; sharp upper contact; sharp, irregular lower contact. |
| Hole at 710.2' 9/23/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Washed hole to 680'. Hole caving badly. Hanging up rods. Mixed & pumped 2 pits of revert in hole. Pulled rods & set 673.0' of 2" pipe in hole. Bottom of pipe at 670.0'. Drove on Nx Cs for 1 hour. | | | | | | | | | | | | 508.0-508.4 MUDSTONE: Gray; hard; carbonaceous; plant fragments; rare; sharp, irregular upper contact; sharp, irregular lower contact. |
| | | | | | | | | | | | | 508.4-512.0 SANDSTONE: Light gray; very fine grained; coarser grained with depth; irregular bedding surfaces; carbonaceous plant fragments (rare near top to increasingly common near bottom) |
| | | | | | | | | | | | | 512.0-527.7 SANDSTONE: Light gray; fine grained; carbonaceous plant fragments; common or irregular bedding surfaces; soft. |
| Hole at 710.2' 9/24/76. 6" Cs at 9.0'. Nx Cs at 502.0'. Hauled equipment to 76-108. Hammered Nx Cs back 6". | | | | | | | | | | | | 527.7-531.5 MUDSTONE: Gray; hard; slickensides; carbonaceous plant fragments; fine to very fine grained, light gray sandstone in places with carbonaceous plant fragments; upper & lower contacts gradational; has mottled (bioturbated) appearance. |
| 9/27/76 - Hammered Nx Cs back 2.0'. Broke slide pipe on hammer. Took to Gillette for repair. | | | | | | | | | | | | 531.5-533.5 SANDSTONE: Dark gray; very fine grained; coaly stems & branches; irregular bedding grades into hard, gray siltstone with rare, finely divided, carbonaceous plant fragments in lower 0.4'. |
| 9/28/76 - Hammered Nx Cs back 10.0'. | | | | | | | | | | | | 533.5-534.6 SILTSTONE: Gray; hard; carbonaceous; plant fragments become more common near bottom; sharp lower contact. |
| 9/29/76 - Hammered Nx Cs back 33.0'. | | | Notes continued 10/4/76 - Returned from duty station. Hauled remaining equipment to DH 76-108. | | | | | | | | | 534.6-536.6 COAL: Flakey; soft; stems & branches; bright & dull bands. |
| 9/30/76 - Hammered & pulled remaining Nx Cs from hole. | | | | | | | | | | | | 536.6-542.0 SILTSTONE: Gray; soft; carbonaceous; plant fragments common at top, becoming more finely divided & less common at 537.6'; grades into very fine grained, light gray sandstone with finely divided plant fragments & soft irregular bedding. |
| 10/1/76 - Pulled 6" Hoystallite equipment to DH 76-108. | | | | | | | | | | | | 542.0-557.0 No core recovered. Driller reported SANDSTONE that washed away. |
| | | | | | | | | | | | | 557.0-563.0 MUDSTONE: Light gray; silty; rare carbonaceous fragments; soft. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (R-series) Ex = 1:1.2", As = 1:1.7/8", Bx = 2:3/8", Hx = 3"
Approx. size of core (R-series) Ex = 7/8", As = 1:1/8", Bx = 1:5/8", Hx = 2:1/8"
Outside dia. of casing (R-series) Ex = 1:1/16", As = 2:1/4", Bx = 2:7/8", Hx = 3:1/2"
Inside dia. of casing (R-series) Ex = 1:1/2", As = 1:29/32", Bx = 2:3/8", Hx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 8 OF 10 HOLE HO 76-103

METERS 0 1 2 3 4 5 6 7 8 9 — FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

## GEOLOGIC LOG OF DH 76-103

GEOLOGY G. J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA SHEET 2 OF 3 MARCH, 1977 1305-600-125

7-1337 (9-69)
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 9 OF 10

FEATURE White Tail Butte Study Site Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO 76-103
LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W.
Altimeter GROUND ELEV 4163±
DIP (ANGLE FROM HORIZ) Vertical
BEGUN 7/29/76
FINISHED 10/4/76
DEPTH OF OVERBURDEN --
TOTAL DEPTH 710.2
BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED
LOGGED BY Goolsby (USGS) below 499.7'
REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 10, 20, 30, 40, 50, 60, 70, 80, 90 | | | 563.0-565.5 MUDSTONE: Gray; silty; grades into black mudstone at 564.0'; becomes coaly near bottom; bottom gradational with coal.<br>565.5-589.3 COAL: Very fractured; hard with conchoidal fractures in places; flakey & soft zones; bright & dull bands; stems & branches in places.<br>589.3-591.0 SHALE: Gray-brown; soft; slickensides; friable; upper contact gradational from coal to carbonaceous shale to shale; lower contact gradational from shale to carbonaceous shale to coal.<br>591.0-592.8 COAL: Flakey; stems & branches; shaley; 0.5' of gray-brown, soft, slickensided, friable shale at 591.5'; top is gradational contact; sharp bottom contact.<br>592.8-600.4 SILTSTONE: Light gray; soft; slickensides; pyrite nodules with occasional bedded pyrite; carbonaceous plant fragments; top 0.5' is coaly siltstone grading into siltstone; light gray, very fine grain, soft, pyritic sandstone (1.5') at 598.0'; sandy in places.<br>600.4-609.0 SANDSTONE: Light gray; very fine grained; soft; scattered pyrite nodules; dark bands becoming more numerous near bottom; some very finely divided carbonaceous plant fragments near bottom.<br>609.0-610.4 MUDSTONE: Gray; hard; silty; gradational contact at top (mottled in appearance); light gray, medium fine grained, salt and pepper sandstone irregularly interbedded with mudstone.<br>610.4-619.0 SANDSTONE: Light gray; fine grained; nearly salt & pepper in appearance.<br>619.0-629.0 SILTSTONE: Dark gray with black streaks; rare finely divided, carbonaceous plant fragments; hard.<br>629.0-647.0 No recovery. Driller reported SANDSTONE.<br>647.0-649.0 MUDSTONE: Dark gray; hard; silty; rare carbonaceous plant fragments; upper & lower contacts gradational. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"
Approx. size of core (X-series) . . Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"
Outside dia. of casing (X-series) . Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"
Inside dia. of casing (X-series) . Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 9 OF 10 HOLE NO 76-103

7-1337 (9-69)
Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 10 OF 10

FEATURE White Tail Butte Study Site Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO 76-103
LOCATION 1000' N. & 330' W. of SE Corner, Sec. 31, T. 56 N., R. 72 W.
Altimeter GROUND ELEV 4163±
DIP (ANGLE FROM HORIZ) Vertical
BEGUN 7/29/76
FINISHED 10/4/76
DEPTH OF OVERBURDEN --
TOTAL DEPTH 710.2
BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED
LOGGED BY Goolsby (USGS) below 499.7'
LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 10, 20, 30, 40, 50, 60, 70, 80, 90 | | | 649.0-659.0 SANDSTONE: Light gray; fine grained; salt & pepper appearance; black streaks; "bedded" pyrite; pebble to granule-sized clay clasts (may be due to drilling).<br>659.0-662.0 SANDSTONE: Light gray; fine grained; salt & pepper appearance; light green to pink clasts.<br>662.0-662.2 SILTSTONE: Dark gray & hard becoming light gray & soft with depth; pyrite along sharp upper contact; some carbonaceous plant fragments.<br>662.2-667.0 SHALE: Dark gray; friable; slickensides; light gray, hard, carbonaceous siltstone 666.4 to 666.6'; sharp contacts above & below siltstone.<br>667.0-683.7 COAL: Flakey in places; hard in zones; gradational coal-shale contact 667.0 to 667.5'; dull & bright bands; vertical fractures; broken; stems & branches.<br>683.7-698.5 MUDSTONE: Light to dark gray; soft; silty; some fine pyrite nodules; finely divided carbonaceous plant fragments; slickensides.<br>698.5-700.5 SANDSTONE: Light gray; very fine grained; "bedded"; pyrite; dark streaks; top contact gradational; sharp lower contact.<br>700.5-701.2 MUDSTONE: Dark gray; soft; carbonaceous plant fragments common; gradational bottom contact.<br>701.2-702.8 SILTSTONE: Gray; soft; sandy in places; 0.4' of coaly material at 702.0'; rare pyrite; becoming more sandy with depth.<br>702.8-710.2 SANDSTONE: Light gray, very fine grained; carbonaceous plant fragments; dark streaks; interbedded with dark gray, silty mudstone; very carbonaceous at 706.0'; mudstone more prominent near bottom. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Es = 1-1/2", As = 1-7/8", Bs = 2-3/8", Ns = 3"
Approx. size of core (X-series) . . Es = 7/8", As = 1-1/8", Bs = 1-5/8", Ns = 2-1/8"
Outside dia. of casing (X-series) . Es = 1-13/16", As = 2-1/4", Bs = 2-7/8", Ns = 3-1/2"
Inside dia. of casing (X-series) . Es = 1-1/2", As = 1-29/32", Bs = 2-3/8", Ns = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 10 OF 10 HOLE NO 76-103

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

**GEOLOGIC LOG OF DH 76-103**

GEOLOGY G. J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1977 SHEET 3 OF 3 | 1305-600-126

Form 1-1337 (1-64) Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming

HOLE NO. 76-104 — LOCATION: 1790' E. & 340' S. of NW Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV: Altimeter 4241± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6/16/76 — FINISHED: 7/19/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 362.5 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 201.5' (4039.5) 7/15/76 — LOGGED BY: Taucher — LOG REVIEWED BY:

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boils Analysis Sample Depth (Feet) From | To | Suitability for Reconstituted Profile: Buildable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole started 6/16/76. Moved equipment from Broadus, Montana. Set up rig and equipment. Nx drive samples 0 to 8.5'. | | 100 | #1 0 | 8.5 | | | | | | | | FT. UNION FORMATION - PALEOCENE<br>0-8.5 SHALE: Tan; oxidized, damp to moist; badly broken to shattered 0 to 6.0'; broken along 60-70° oxidized gypsum lined joints on 3 to 6" centers 6.0 to 8.5'; active HCl reaction; gypsum crystals scattered in core; plastic; trims easily with knife. |
| 6/17/76. Unable to get to site because of rain & muddy roads. | | 100 | #2 8.5 | 12.5 | | | | 4232.5 | 8.5 | | | |
| Hole at 8.5' 6/18/76. Set 5" Ca to 9.0'. Hq wireline core 8.5 to 33.5'. 50I water loss at 26.0'. Repairs on equipment. | | 86 | | | | | | 4228.5 | 12.5 | | | 8.5-12.5 SANDSTONE: Light gray to tan; oxidized; damp; silty; fine grain; crumbles easily between fingers; uncemented; few laminations 11.5 to 12.5'; slight HCl reaction; scattered gypsum crystals; core length= 3". |
| Hole at 33.5' 6/21/76. 5" Ca at 9.0'. Pulled 5" Ca. Reamed hole to 33.5'. Set 5" Ca to 33.5'. Hq wireline core 33.5 to 53.5'. Total water loss at 44.5'. Hole caving at 30.1'. | | 83 | #3 15.3 | 23.5 | | | | 4227.0 | 16.0 | | | |
| Hole at 33.5' 6/22/76. 5" Ca at 9.0'. W.L. at 31.2'. Hq wireline core 53.5 to 102.8'. Used drill mud (bentonite) at start of shift. 100I water loss at 66.0'. | | 100 | #4 23.5 | 53.5 | | | | 4225.7 | 15.3 | | | 12.5-14.0 LIMESTONE: Dark gray; moist; hard; scratches with knife. |
| | | 42 | | | | | | 4217.5 | 23.5 | | | 14.0-15.3 LIMESTONE & SILTY SANDSTONE: Tan; damp; oxidized; alternating laminations of uncemented, fine grain silty sandstone (crushes easily between fingers) & low to medium plasticity silty shale (trims easily by knife); active HCl reaction; bedding dips 30° at 16.0' & 25° at 23.8'; badly broken; maximum core length 2". |
| | | 100 | #5 53.5 | 102.8 | | | | | | | | 23.5-102.8 SILTY SHALE: Tan to light gray with occasional brick-red bands; moist; soft; oxidized; indents easily with thumb in most places; moderately plastic; bedding where discernible dips from 10 to 45°; moderate HCl reaction; silty; approaching clayey siltstone in pieces; 60 to 90° oxidized (red), gypsum lined joints 40.0 to 41.5, 44.5 to 44.8, 45.0 to 45.3 & 48.5 to 48.7'; carbonaceous 62.5 to 62.6 & 79.0 to 80.0'(?); 2-30° opposing gypsum lined joints at 94.0'; highly oxidized, yellow-brown, soft, mushy clayey siltstone 97.8 to 102.8'; shattered 23.5 to 33.0 & 42.0 to 53.5'; remaining core is in 1 to 6" lengths. NOTE: Material 0 to 102.8' is collapse over burned out Anderson Coalbed (base at 102.8'). Material is not highly altered by heat & does not appear similar to clinker encountered in other drill holes (DH 76-109 - Bear Creek Study Site, Montana). |
| | | 53 | | | | | | | | | | |
| | | 72 | | | | | | | | | | 102.8-153.3 SILTY TO SANDY SHALE & SILTY SANDSTONE: Silty to sandy shale in light gray; moderately firm, moderately plastic |

EXPLANATION

CORE LOSS — CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoyatallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cement, Cs = Bottom of casing
Approx. size of hole (R-series) ..... Ex = 1:1.3", As = 1:7.8", Ba = 3:3.8", Mx = 3"
Approx. size of core (R-series) ..... Ex = 7/8", As = 1:1.8", Ba = 1:5.8", Mx = 2:1.8"
Outside dia. of casing (R-series) ..... Ex = 1:13.18", As = 2:1.4", Ba = 2:7.8", Mx = 3:1.2"
Inside dia. of casing (R-series) ..... Ex = 1:1.2", As = 1:29.32", Ba = 2:3.8", Mx = 3"

Form 1-1337 (1-64) Bureau of Reclamation — FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 1 OF 4 — HOLE NO. 76-104

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming

HOLE NO. 76-104 — LOCATION: 1790' E. & 340' S. of NW Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV: Altimeter 4241± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6/16/76 — FINISHED: 7/19/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 362.5 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 201.5 (4039.5) 7/15/76 — LOGGED BY: Taucher — LOG REVIEWED BY:

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boils Analysis Sample Depth (Feet) From | To | Suitability for Reconstituted Profile: Buildable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 102.8' 6/23/76. 5" Ca at 33.5'. Caved at 90.0'. Dry to 90.0'. Hq wireline core 102.8 to 153.3'. Hauled 5 loads of water (4,000 gallons). Very soft 130.6 to 153.3'. (No hydraulic pressure used). Water truck slid off of road. | | 100 | #6 102.8 153.3 | | | | | 4138.2 | 102.8 | | | and trims easily with knife, silty sandstone is light gray, uncemented, fine grain & crushes easily between fingers; moist; core lengths 1 to 12" (average 8"). |
| Hole at 153.3' 6/24/76. 5" Ca at 33.5'. Hole dry to core at 91.0'. 1½ loads of water used washing out core 91 to 153.3'. Hq wireline core 153.3 to 203.3'. Unable to recover sandy material which washed away. 100I drill water loss. | | 92 | | | | | | | | | | 102.8-130.0 - Silty to sandy shale; uncemented silty sandstone with marcasite nodules 106.5 to 106.6'; ½" marcasite nodule along bedding plane at 111.0'; clayey fine grain sandstone 112.0 to 112.6'; 2 opposing 80° joints at 112.0'; becoming more sandy (shaley sandstone) below 124.8'. 130.0-153.3 - Core recovered was firm, plastic, medium gray shale with severe sand streaks. Driller reported that firm shale zones were recovered but soft sandstone (?) zones washed away. No drill water return at surface. Probably interbedded, uncemented fine grain sandstone and shale. |
| 6/25/76 - Worked on rig and water pump. | | 150 | 9 | | | | | | | | | |
| 6/28/76 - Worked on rig and water pump. | | | 27 | | | | | 4087.7 | 153.3 | | | 153.3-162.7 SANDSTONE: No core. Driller reported uncemented, fine grain sandstone that washed away during drilling. Several hard, round pyrite or marcasite nodules recovered. |
| 6/29/76 - Worked on rig and water pump. Cleaned hole to 203.3'. Hole caved at 89.0'. | | 160 | 9 | | | | | 4078.3 | 162.7 | | | 162.7-163.0 COAL: Black; moist; broken. |
| | | 100 | 17 | | | | | 4078.0 | 163.0 | | | 163.0-203.3 CLAYEY SANDSTONE TO SANDY SHALE: Clayey sandstone zones are light to medium gray and uncemented; sandy shale is medium gray & moderately plastic; firm; trims by knife with difficulty; moist; slight HCl reaction in sandy zones; moist; core lengths 1 to 12" (average 6"). 164.3-167.0 - Sandy shale. 167.0-170.3 - Clayey sandstone. 170.3-173.3 - Sandy shale with 30I clayey sandstone zones. 173.3-199.0 - Alternating zones of clayey sandstone & sandy shale. 199.0-203.3 - Sandy shale. |
| | | 50 | #7 162.7 203.3 | | | | | | | | | 203.3-220.0 SILTY SHALE & SILTY SANDSTONE: Alternating laminations of medium gray, plastic silty shale (trims by knife with some difficulty) & uncemented, fine-grain light gray silty sandstone (crumbles easily between fingers); moist; very slight HCl reaction; bedding dips horizontal at 210° & 30° at 218°; core lengths 6"; scattered pyrite nodules. |
| | | 40 | | | | | | | | | | 220.0-239.0 SHALE & SANDY SHALE: Medium gray; moist; trims by knife with some difficulty; plastic; bedding dips 5° at 230 and 20° at 237; sandy becoming sandy |

BASE OF ANDERSON CLINKER

EXPLANATION

CORE LOSS — CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoyatallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cement, Cs = Bottom of casing
Approx. size of hole (R-series) ..... Ex = 1:1.3", As = 1:7.8", Ba = 3:3.8", Mx = 3"
Approx. size of core (R-series) ..... Ex = 7/8", As = 1:1.8", Ba = 1:5.8", Mx = 2:1.8"
Outside dia. of casing (R-series) ..... Ex = 1:13.18", As = 2:1.4", Ba = 2:7.8", Mx = 3:1.2"
Inside dia. of casing (R-series) ..... Ex = 1:1.2", As = 1:29.32", Ba = 2:3.8", Mx = 3"

Form 1-1337 (1-64) Bureau of Reclamation — FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 2 OF 4 — HOLE NO. 76-104

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming

HOLE NO. 76-104 — LOCATION: 1790' E. & 340' S. of NW Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV: Altimeter 4241± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6/16/76 — FINISHED: 7/19/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 362.5 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 201.5 (4039.5) 7/15/76 — LOGGED BY: Taucher — LOG REVIEWED BY:

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boils Analysis Sample Depth (Feet) From | To | Suitability for Reconstituted Profile: Buildable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 203.3' 6/30/76. 5" Ca at 33.5'. Hole caved at 89.0'. Washed Nx Ca to 204.5'. Nx wireline core 204.5 to 224.0'. Used 1600 gallons of water. Lost water 204.5 to 214.0'. | | 210 | #8 204.5 222.0 | | | | | 4037.7 | 203.3 | | | with occasional laminated sandy shale, silty sandstone & sandstone zones below 231.0' (90I shale); core lengths 1 to 8". |
| Hole at 224.0' 7/1/76. 5" Ca at 33.5'. Nx Ca at 204.5'. W.L. at 192.0'. Set Nx Ca to 214.5'. Nx wireline core 224.0 to 253.5'. Using reverb. Losing 20I drill water return. Used 1600 gallons of water. | | 220 | | | | | | 4021.0 | 220 | | | 239.0-240.5 LIMESTONE: Medium gray; hard; cemented; scratches with knife; unbroken. |
| Hole at 253.5' 7/7/76. 5" Ca at 33.5'. Nx Ca at 214.5'. W.L. at 192.3'. Nx wireline core 253.5 to 263.5. Discontinued drilling at 10:00 a.m. due to heavy rain and lightning. | | 230 | #9 222.0 239.0 | | | | | | 230 | | | 240.5-245.0 CLAYEY SANDSTONE: Light to medium gray; moist; firm; trims by knife with difficulty; moderately plastic; grades to sandy shale in places; sand is very fine grain; slight HCl reaction; core lengths 1 to 6". |
| Hole at 263.5' 7/7/76. 5" Ca at 33.5'. Nx Ca at 214.5'. W.L. below 198'. Nx wireline core 263.5 to 269.5. Repairs on pump. Did not drill on 7/6/76. | | 260 | #10 245.0 255.0 | | | | | 4002.0 | 239 | | | 245.0-255.0 SHALE: Medium gray; moist; firm; difficult trimming by knife; plastic; bedding not readily discernible; air slacks; 80° joint at 249.0'; core lengths 2 to 18" (Av. 8") |
| Hole at 269.5' 7/8/76. 5" Ca at 33.5'. Nx Ca at 214.5'. W.L. at 201.2'. Nx wireline core 269.5 to 287.5. 75I water loss at 277.5'. Repairs on water truck. | | 280 | #11 255.0 263.5 | | | | | 4000.5 | 240 | | | 255.0-263.5 SILTY TO SANDY SHALE: Light gray; moist; firm; difficult trimming by knife; thin-bedded; sand is very fine grain; approaching shaley sandstone in places; dip varies from horizontal to 5°; core lengths 1 to 3". |
| | | | #12 263.5 274.0 | | | | | 3996.0 | 245 | | | 263.5-274.0 SHALE: Medium gray; moist; firm; difficult trimming by knife; plastic; scattered silt laminations; air slacks in zones; dip varies from horizontal to 5°; cemented sandstone 264.7 to 264.9'; core lengths 1 to 6". |
| | | | #13 274.0 283.6 | | | | | 3986.0 | 255 | | | 274.0-283.6 SHALE WITH COAL: Dark gray to black; moist; firm; difficult trimming by knife; carbonaceous; plastic; cut by occasional slickensided; alternating layers of carbonaceous shale & coal (20I of sample) 274.0 to 275.5'. |
| | | | #14 283.6 294.0 | | | | | 3977.5 | 263.5 | | | 283.6-294.0 SHALE: Medium gray becoming dark gray to black below 287.5'; moist; moderately firm; cuts easily with knife; plastic; air slacks; highly carbonaceous below 287.5' with ½ to 1" coal streaks (10I of sample). |
| | | | | | | | | 3967.0 | 274 | | | 294.0-315.5 COAL: Sampled and bagged in field. No sample left for logging. |
| | | | | | | | | 3957.4 | 283.6 | | | 315.5-321.9 SHALE: Medium gray 315.5 to 318.7'; dark gray 318.7 to 321.7'; moist; plastic; firm; trims easily with knife; air slacks; badly broken 315.5 to 316.5'; [illegible] = 115.7'. core lengths 1 to 6". |
| | | | | | | | | 3947.0 | 294.0 | | | |

EXPLANATION

CORE LOSS — CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoyatallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cement, Cs = Bottom of casing
Approx. size of hole (R-series) ..... Ex = 1:1.3", As = 1:7.8", Ba = 3:3.8", Mx = 3"
Approx. size of core (R-series) ..... Ex = 7/8", As = 1:1.8", Ba = 1:5.8", Mx = 2:1.8"
Outside dia. of casing (R-series) ..... Ex = 1:13.18", As = 2:1.4", Ba = 2:7.8", Mx = 3:1.2"
Inside dia. of casing (R-series) ..... Ex = 1:1.2", As = 1:29.32", Ba = 2:3.8", Mx = 3"

Form 1-1337 (1-64) Bureau of Reclamation — FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 3 OF 4 — HOLE NO. 76-104

# GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming

HOLE NO. 76-104 — LOCATION: 1790' E. & 340' S. of NW Corner, Sec. 31, T. 56 N., R. 72 W. — GROUND ELEV: Altimeter 4241± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 6/16/76 — FINISHED: 7/19/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 362.5 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 201.5 (4039.5) 7/15/76 — LOGGED BY: Taucher — LOG REVIEWED BY:

| Notes on Water Losses and Levels, Casing, Cementing, Caving, and Other Drilling Conditions | Type and Size of Hole | Core Recovery (%) | Boils Analysis Sample Depth (Feet) From | To | Suitability for Reconstituted Profile: Buildable | Limited Suitability | Unsuitable | Elev. (Feet) | Depth (Feet) | Graphic Log | Samples for Testing | Classification and Physical Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 287.5' 7/12/76. 5" Ca at 33.5'. Nx Ca at 214.5'. W.L. at 201.2'. Nx wireline core 287.5 to 307.5'. 75I drill water loss. | | 100 | | | | | | | | | | 321.9-343.0 COAL: Sampled and bagged in field. No sample left for logging. |
| Hole at 307.5' 7/13/76. 5" Ca at 33.5'. Nx Ca at 214.5'. W.L. at 201.5'. Nx wireline core 307.5 to 326.5'. | | 100 | #15 315.5 321.9 | | | | | 3925.5 | 315.5 | DEIZ | | 343.0-356.5 SHALE: Medium gray; moist; silty; firm; trims by knife with difficulty; plastic; cut by slickenside on about 6" centers 343.0 to 346.0'; dark gray & carbonaceous 346.0 to 346.5'; becoming sandy shale or shaley fine grain sandstone 349.0 to 349.5'; slickensides on 3 to 6" centers 355.0 to 356.5'; core lengths up to 6". |
| Hole at 326.5' 7/14/76. 5" Ca at 33.5'. Nx Ca at 214.5'. W.L. at 201.5'. Nx wireline core 326.5 to 356.5. Hole caved to 270.0' at start of shift. | | 100 | | | | | | 3919.1 | 321.9 | | | 356.5-362.5 SANDSTONE (?): Only 1" core recovery; sample consisted of firm, slightly calcareous cemented, fine grain sandstone; difficult crushing between fingers; driller reported material was hard. |
| Hole at 356.5' 7/15/76. 5" Ca at 33.5'. Nx Ca at 214.5'. W.L. at 201.5'. Nx wireline core 356.5 to 362.5'. Hole completed. USGS run geophysical logs on drill hole. | | 100 | #16 343.0 356.5 | | | | | 3898.0 | 343.0 | CANYON | | |
| 7/16/76 - Moved equipment to DH76-105. | | 100 | | | | | | 3884.5 | 356.5 | | | |
| 7/19/76 - Pulled Nx Ca and completed move to DH76-105. | | 100 | | | | | | 3878.5 | 362.5 | | | |

EXPLANATION

CORE LOSS — CORE RECOVERY

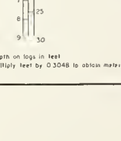
Type of hole ..... D = Diamond, H = Hoyatallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cement, Cs = Bottom of casing
Approx. size of hole (R-series) ..... Ex = 1:1.3", As = 1:7.8", Ba = 3:3.8", Mx = 3"
Approx. size of core (R-series) ..... Ex = 7/8", As = 1:1.8", Ba = 1:5.8", Mx = 2:1.8"
Outside dia. of casing (R-series) ..... Ex = 1:13.18", As = 2:1.4", Ba = 2:7.8", Mx = 3:1.2"
Inside dia. of casing (R-series) ..... Ex = 1:1.2", As = 1:29.32", Ba = 2:3.8", Mx = 3"

Form 1-1337 (1-64) Bureau of Reclamation — FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 4 OF 4 — HOLE NO. 76-104

## SOIL ANALYSES OF DRILL CORE

| Lab Number | Boring Number | Depth in Feet | Field Texture | Particle Size Analysis % Sand .05 to 2 mm: Very Coarse | Coarse | Medium | Fine | Very Fine | % Silt | % 2 μ Clay | Lab Text | Moisture Retention % Pressure in Bars: 0.10 | 0.33 | 15. | Hyd Cond in/hrs: 6 Hr | 24 Hr. | Sat Vol ml | pH @ 25 $H_2O$ 1:5 | $CaCl_2$ | Ec×10³ @ 25°C | Saturation Extract Cations, me/l: Ca | Mg | Na | K | Σ Cations | Anions, me/l: $CO_3$ | $HCO_3$ | Cl | $SO_4$ | Σ Anions | SAR | SP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6851 | 76-104 | 00-8.5 | | | | | | | 68.0 | 29.8 | SiCL | 46.0 | 36.6 | 23.5 | 0.04 | 0.05 | 32 | 7.9 | 7.9 | 3.7 | 4.8 | 24.85 | 60.69 | 15.35 | 1.20 | 102.09 | 0.00 | 1.36 | 1.88 | 101.85 | <0.01 | 3.9 | 79.5 |
| 2 | | 8.5-12.5 | | | | | | | 26.2 | 27.0 | SCL | 41.0 | 29.5 | 14.1 | 0.30 | 0.29 | 26 | 8.5 | 8.1 | 1.7 | 7.0 | 11.78 | 45.71 | 38.39 | 0.98 | 96.81 | 0.00 | 1.80 | 1.64 | 101.48 | <0.01 | 6.2 | 58.7 |
| 3 | | 15.3-23.5 | | | | | | | 57.6 | 28.4 | SiCL | 44.5 | 37.0 | 16.7 | 0.07 | 0.07 | 27 | 8.2 | 7.8 | 2.1 | 7.5 | 21.96 | 52.71 | 34.00 | 1.05 | 109.72 | 0.00 | 1.69 | 1.20 | 92.73 | 1.74 | 5.5 | 63.3 |
| 4 | | 23.5-53.5 | | | | | | | 74.3 | 25.2 | SiL | 45.8 | 38.8 | 22.7 | 0.04 | 0.04 | 32 | 8.2 | 7.6 | 0.98 | 4.0 | 11.83 | 14.47 | 19.13 | 0.80 | 46.23 | 0.00 | 1.92 | 1.04 | 37.04 | 3.15 | 5.3 | 80.1 |
| 5 | | 53.5-102.8 | | | | | | | 68.4 | 30.6 | SiCL | 37.2 | 29.7 | 19.3 | 0.03 | 0.04 | 29 | 8.2 | 7.5 | 1.8 | 4.5 | 27.04 | 19.16 | 19.78 | 1.49 | 67.47 | 0.00 | 1.52 | 0.64 | 49.37 | 4.60 | 4.1 | 67.0 |
| 6 | | 102.8-153.3 | | | | | | | 47.6 | 39.0 | SiCL | | | 17.2 | 0.02 | 0.02 | 29 | 7.3 | 6.6 | 1.5 | 4.5 | 26.40 | 25.00 | 13.04 | 2.51 | 66.95 | 0.00 | 1.56 | 0.04 | 55.72 | 0.08 | 2.6 | 63.1 |
| 7 | | 162.7-203.3 | | | | | | | 41.0 | 35.6 | CL | 37.0 | 30.5 | 14.6 | 0.04 | 0.05 | 30 | 8.1 | 7.8 | 0.42 | 3.9 | 26.10 | 20.97 | 10.55 | 2.05 | 59.67 | 0.00 | 3.24 | 0.08 | 45.80 | 0.02 | 2.1 | 56.0 |
| 8 | | 203.5-220.0 | | | | | | | 38.9 | 34.4 | CL | 36.7 | 30.2 | 13.0 | 0.03 | 0.03 | 25 | 7.9 | 7.6 | 0.34 | 2.2 | 9.93 | 7.96 | 6.39 | 1.14 | 25.42 | 0.00 | 3.48 | 0.28 | 18.82 | <0.02 | 2.1 | 51.2 |
| 9 | | 220.0-230.0 | | | | | | | 51.2 | 41.4 | SiC | 39.2 | 31.8 | 16.4 | 0.01 | 0.02 | 29 | 8.3 | 7.8 | 0.40 | 1.8 | 8.58 | 7.42 | 7.52 | 1.21 | 24.73 | 0.24 | 4.16 | 0.44 | 17.70 | <0.02 | 2.7 | 66.3 |
| 60 | | 245.0-255.0 | | | | | | | 53.3 | 44.0 | SiC | 40.6 | 33.0 | 20.3 | 0.00 | 0.00 | 45 | 8.5 | 7.8 | 0.30 | 1.5 | 3.29 | 2.68 | 8.52 | 0.79 | 15.22 | 0.32 | 3.88 | 0.08 | 10.01 | <0.02 | 5.0 | 69.6 |
| 1 | | 255.0-263.5 | | | | | | | 48.5 | 31.4 | CL | 34.5 | 28.1 | 11.6 | <0.01 | 0.01 | 30 | 8.2 | 7.6 | 0.26 | 1.1 | 2.14 | 1.63 | 8.04 | 0.62 | 12.43 | 0.16 | 3.32 | 0.32 | 7.29 | <0.02 | 5.9 | 49.5 |
| 2 | | 263.5-274.0 | | | | | | | 53.6 | 44.4 | SiC | 38.5 | 31.3 | 18.3 | 0.00 | 0.00 | 37 | 7.8 | 7.6 | 0.36 | 2.2 | 4.72 | 5.34 | 12.13 | 0.97 | 23.16 | 0.00 | 3.24 | 0.88 | 0.04 | 5.4 | 68.8 | 0.30 |
| 3 | | 274.0-284.6 | | | | | | | 25.4 | 70.4 | C | 45.5 | 38.3 | 22.5 | 0.00 | 0.00 | 50 | 7.1 | 6.5 | 0.39 | 1.2 | 2.74 | 2.26 | 0.52 | 0.59 | 16.11 | 0.00 | 2.44 | 0.26 | 11.78 | 0.09 | 6.7 | 75.9 |
| 4 | | 284.6-294.0 | | | | | | | 19.2 | 72.0 | C | 51.9 | 42.9 | 25.5 | 0.00 | 0.02 | 38 | 5.4 | 4.8 | 1.4 | 4.5 | 27.89 | 22.37 | 19.48 | 1.18 | 70.92 | 0.00 | 1.68 | 0.20 | 65.50 | 0.04 | 3.9 | 94.6 |
| 5 | | 315.5-321.9 | | | | | | | 33.0 | 61.0 | C | 41.5 | 35.0 | 19.6 | 0.00 | 0.00 | 60 | 7.4 | 6.5 | 0.40 | 1.9 | 3.15 | 2.53 | 12.57 | 0.69 | 18.92 | 0.00 | 5.00 | 1.24 | 13.34 | 0.16 | 7.5 | 63.4 |
| 6866 | | 343.0-356.5 | | | | | | | 45.1 | 49.8 | SiC | 42.8 | 35.3 | 19.0 | 0.00 | 0.00 | 40 | 7.4 | 7.0 | 0.40 | 1.9 | 5.04 | 3.71 | 14.83 | 1.07 | 24.65 | 0.00 | 3.64 | 0.04 | 18.24 | 0.06 | 7.1 | 68.4 |

| Lab Number | Total Extractable Cations me/100g: Ca | Mg | Na | K | Exchangeable Cations me/100g: Ca | Mg | Na | K | ESP | % Base Sat | Gyp Req me/100g | Gyp Req | CEC me/100g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6851 | | | 2.61 | 0.45 | | | 0.59 | 0.35 | 2.0 | | 2.1 | -16. | 29.7 |
| 2 | | | 3.57 | 0.30 | | | 1.32 | 0.29 | 5.3 | | 5.3 | -38 | 24.8 |
| 3 | | | 3.22 | 0.42 | | | 1.00 | 0.33 | 3.9 | | 7.8 | -56 | 25.8 |
| 4 | | | 2.26 | 0.50 | | | 0.63 | 0.44 | 2.2 | | 1.6 | -0.9 | 28.8 |
| 5 | | | 2.09 | 1.05 | | | 0.76 | 0.94 | 2.5 | | 7.0 | -5.7 | 30.6 |
| 6 | | | 1.04 | 0.70 | | | 0.22 | 0.54 | 0.9 | | 5.8 | -5.9 | 24.2 |
| 7 | | | 0.61 | 0.45 | | | 0.03 | 0.34 | 0.2 | | 0.9 | -2.8 | 18.0 |
| 8 | | | 0.76 | 0.45 | | | 0.19 | 0.39 | 1.0 | | 0.8 | -0.4 | 18.3 |
| 9 | | | 1.30 | 0.44 | | | 0.46 | 0.36 | 2.4 | | 0.9 | -0.5 | 18.8 |
| 60 | | | 0.96 | 0.46 | | | 0.71 | 0.41 | 3.5 | | 0.5 | +0.2 | 20.0 |
| 1 | | | 1.48 | 0.27 | | | 0.56 | 0.24 | 4.3 | | 1.0 | -0.3 | 18.0 |
| 2 | | | 2.00 | 0.47 | | | 0.71 | 0.41 | 3.9 | | 0.8 | +0.4 | 18.0 |
| 3 | | | 2.00 | 0.51 | | | 1.20 | 0.47 | 4.7 | | 0.8 | +1.4 | 25.6 |
| 4 | | | 2.85 | 0.47 | | | 0.51 | 0.36 | 1.6 | | 4.2 | -3.6 | 32.3 |
| 5 | | | 1.91 | 0.41 | | | 1.11 | 0.37 | 4.3 | | 0.7 | +1.1 | 23.6 |
| 6 | | | 1.98 | 0.50 | | | 1.08 | 0.53 | 5.3 | | 0.8 | +1.1 | 20.3 |




UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH 76-104

GEOLOGY: G. J. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:

BILLINGS, MONTANA — MARCH, 1977 — SHEET 1 OF 1

1305-600-127

7-1337 (6-63) Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE White Tail Butte Study Site Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming

HOLE NO 76-105 — LOCATION 1350' N. & 1410' W. of SE Corner, Sec. 30, T. 56 N., R. 72 W. — GROUND ELEV Altimeter 4187± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7/20/76 — FINISHED 7/28/76 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 275.0 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 92.3' 7/22/76 (4096.7') — LOGGED BY Taucher — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | Core recovery (%) | Boils analysis sample (depth, feet) | Suitability for reconstructed profile | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|
| 7/19/76 - Moved equipment to drill site.<br>Hole started 7/20/76. Na drive samples: 0 to 6.5'. Hq wireline core 6.5 to 82.0'. No water loss. Dropped some core in hole from runs 23.5 to 33.5 & 43.0 to 45.5'. Ground up core trying to recover. 6" Cs set to 4.0'.<br>Hole at 82.0' 7/21/76. 6" Cs at 4.0'. W.L. at 29.3'. Hq wireline core 82.0 to 145.0' 10% water loss at about 90'. Using revert below 125.0' Core blocking in barrel in coal zone. | 100; 0; 50; 100; 100; #1 0 (from 43.5); 65; 84; 0; 63; #2 (from 67.5, to 47.8); 90; 100; 80; 100; 100; 71 | | | 4141.5 43.5; 4139.2 47.8; 4119.5 67.5; 4115.0 72.0; 4114.2 72.8; 4088.7 98.3 | 10; 20; 30; 40; 50; 60; 70; 80; 90 | ANDERSON | | FT. UNION FORMATION - PALEOCENE<br>0-45.5 SILTY SHALE: Tan( oxidized; dry 0 to 2.5', becoming moist below 2.5'; moderately firm; trims easily with knife; moderate to active acid reaction silty; very silty (clayey siltstone) 0 to 5.0'; moderately plastic; siliceous cemented siltstone 10.8 to 11.0 & 28.3 to 28.5'; 80° , 1/32-inch gypsum-lined joint 23.5 to 24.5'; alternating tan & gray shale 37.7 to 43.0'; no core 43.0 to 45.5'; core lengths 1 to 8" (average 4").<br>45.5-47.8 CARBONACEOUS SHALE & COAL: Black, carbonaceous, plastic shale 45.5 to 46.3 & 46.8 to 47.0'; medium gray, slightly carbonaceous silty sandstone 46.3 to 46.8'; coal 47.0 to 47.8'; moist; firm; some gypsum along bedding planes.<br>47.8-67.5 SHALE: Medium gray near top grading to dark gray, carbonaceous shale with depth; moist; firm; trims by knife with difficulty; plastic; air slacks; bedding not readily discernible; tan, oxidized silty sandstone 47.8 to 48.6'; carbonaceous with gypsum inclusions 48.6 to 48.7'; gypsum lined 45° joint at 53.2'; 70° joint at 58.0'; several 45° slickensides 61.5 to 61.8'; approaching claystone in places; core lengths 2 to 8".<br>67.5-72.0 COAL: Black; moist; dull; broken; no sample viable for inspection as core was bagged in the field.<br>72.0-72.8 SHALE: Black; moist; firm; trims by knife; plastic; carbonaceous; unbroken.<br>72.8-98.3 COAL: Black; moist; dull; broken; not viable for inspection as core was sampled and bagged in field.<br>98.3-113.5 SHALE: Dark gray & slightly carbonaceous 98.3 to 100.5'; black & highly carbonaceous with thin coal streaks 100.5 to 105.0'; medium gray 105.0 to 113.5'; moist; firm; difficult trimming by knife except soft, carbonaceous zone 100.5 to 105.0'; plastic; occasional pyrite or marcasite nodules developed along bedding planes below 105.0'; 1" pyrite cluster along horizontal bedding plane at 113.5'; air slacks; weak HCl reaction; core lengths 2 to 6" |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, H = Hoyatellite, S = Shot, C = Chain
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (R series): Ex = 1:1-2", Ax = 1:7-8", Bx = 2:3-8", Nx = 3"
Approx. size of core (R series): Ex = 7-8", Ax = 1:1-8", Bx = 1:5-8", Nx = 2:1-8"
Outside dia. of casing (R series): Ex = 1:13/16", Ax = 2:1-8", Bx = 2:7-8", Nx = 3:1/2"
Inside dia. of casing (R series): Ex = 1:1-2", Ax = 1:29/32", Bx = 2:3-8", Nx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 1 OF 3 — HOLE NO 76-105

7-1337 (6-63) Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE White Tail Butte Study Site Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming

HOLE NO 76-105 — LOCATION 1350' N. & 1410' W. of SE Corner, Sec. 30, T. 56 N., R. 72 W. — GROUND ELEV Altimeter 4187± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7/20/76 — FINISHED 7/28/76 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 275.0 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 92.3' 7/22/76 (4096.7') — LOGGED BY Taucher — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | Core recovery (%) | Boils analysis sample (depth, feet) | Suitability for reconstructed profile | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|
| Hole at 145.0' 7/22/76. 6" Cs at 4.0'. W.L. at 92.3'. Hq wireline core 145.0 to 215.0'. Lost water 185.0 to 195.0'. Regained water near bottom of hole. Using revert.<br>7/23 and 7/26/76. Repairs on equipment. Trip to duty station. | 100; #3 98.3 (from 113.5); 110; 100; 120; 60; #4 113.5 (from 133.5); 130; 100; 140; 100; 65; #5 133.5 (from 175.0); 160; 100; 170; 100; #6 175.0 (from 185.0); 180; 100; 190; 100; 85 | | | 4073.5 113.5; 4053.5 133.5; 4012.0 175.0; 4002.0 185.0 | 110; 120; 130; 140; 150; 160; 170; 180; 190 | DIETZ F | | 113.5-133.5 SANDSTONE & SHALE: Sandstone is light gray, silty, fine grain & uncemented (crumbles easily between fingers); shale is light to medium gray, silty, moderately plastic to plastic & firm (difficult trimming by knife); moist; slight HCl reaction; core lengths up to 12" (average 6").<br>113.5-114.0 - Silty sandstone with pyrite clusters up to ¼" in diameter.<br>114.0-115.0 - Silty shale with sandstone streaks.<br>115.0-125.0 - Silty sandstone with shale lenses at 115.8 to 116.1, 117.3 to 117.9 & 118.3 to 118.8'.<br>125.0-126.0 - Dark gray, plastic, carbonaceous shale.<br>126.0-127.6 - Clayey sandstone with silty shale 126.7 to 127.1'.<br>127.6-128.5 - Silty shale.<br>128.5-128.8 - Broken coal.<br>128.8-130.0 - Sandstone.<br>130.0-131.0 - Silty shale.<br>131.0-133.5 - Sandstone.<br>133.5-175.0 SANDSTONE, SHALEY SANDSTONE, SANDY SHALE & SHALE: Sandstones are light gray, fine grain, uncemented and contain varying amounts of silt & clay; shales are medium gray, firm, plastic, & contain various amounts of fine sand; moist; generally trims easily by knife; weak HCl reaction; scattered pyrite or marcasite nodules generally in more sandy areas; core lengths up to 12".<br>133.5-138.0 - Sandy shale grading to shaley sandstone with depth.<br>138.0-139.5 - Sandstone with shaley sandstone 138.5 to 138.9'.<br>139.5-148.0 - Sandy shale.<br>148.0-150.1 - Shaley sandstone.<br>150.1-175.0 - Sandy shale with shaley sandstone zones 155.7 to 156.1, 157.5 to 158.2 & 167.5 to 168.5'.<br>175.0-185.0 CARBONACEOUS SHALE: Dark gray & moderately carbonaceous 175.0 to 176.5'; black & highly carbonaceous 176.5 to 185.0'; moist; firm; trims easily by knife; plastic; air slacks; core lengths 1 to 6".<br>185.0-204.3 COAL: Black; moist; dull; no coal visible for inspection as coal was bagged & sampled in field.<br>204.3-239.5 SANDY SHALE WITH SHALE & SANDSTONE: Sandy shale is banded to mottled light to medium gray, firm & |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, H = Hoyatellite, S = Shot, C = Chain
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (R series): Ex = 1:1-2", Ax = 1:7-8", Bx = 2:3-8", Nx = 3"
Approx. size of core (R series): Ex = 7-8", Ax = 1:1-8", Bx = 1:5-8", Nx = 2:1/8"
Outside dia. of casing (R series): Ex = 1:13/16", Ax = 2:1-8", Bx = 2:7-8", Nx = 3:1/2"
Inside dia. of casing (R series): Ex = 1:1-2", Ax = 1:29/32", Bx = 2:3-8", Nx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 2 OF 3 — HOLE NO 76-105

7-1337 (6-63) Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE White Tail Butte Study Site Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming

HOLE NO 76-105 — LOCATION 1350' N. & 1410' W. of SE Corner, Sec. 30, T. 56 N., R. 72 W. — GROUND ELEV Altimeter 4187± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7/20/76 — FINISHED 7/28/76 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 275.0 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 92.3' 7/22/76 (4096.7') — LOGGED BY Taucher — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | Core recovery (%) | Boils analysis sample (depth, feet) | Suitability for reconstructed profile | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|
| Hole at 215.0' 7/27/76. 6" Cs at 4.0'. Hole dry to 114.5'. Washed core in hole from 114.5 to 215.0'. Hq wireline core 215.0 to 275.0'. 100% water loss below 239.5'. Used 4000 gallons of water.<br>Hole at 275.0' 7/28/76. 6" Cs at 4.0'. Hole caved at 120.0'. Washed out hole for geophysical logging. Pulled casing & moved to DH76-103 | 210; 100; #7 204.3 (from 229.6); 220; 70; 230; 90; 240; 90; 84; #8 259.0 (from 275.0); 270; 87; 290 | | | 3982.7 204.3; 3947.5 239.5; 3928.0 259.0; 3912.0 275.0 | 210; 220; 230; 240; 250; 260; 270; 280; 290 | CANYON G | | difficult trimming by knife; shale is medium gray, plastic, firm & difficult trimming by knife; sandstone is light gray, fine grain, uncemented & crushes easily between fingers; moist; core lengths up to 12".<br>204.3-205.0 - Dark gray, plastic carbonaceous shale.<br>205.0-208.0 - Medium gray plastic shale.<br>208.0-212.5 - Alternating laminations of shale (65%) and sandstone (35%).<br>212.5-217.0 - Sandstone (75%) with silty shale streaks (25%).<br>217.0-236.2 - Sandy shale with about 20% being sandstone streaks.<br>236.2-239.5 - Dark gray, plastic, carbonaceous shale.<br>239.5-259.0 COAL: Black; moist; dull; not viable for inspection as coal was sampled & bagged in field.<br>259.0-266.9 SANDY SHALE: Light to medium gray; moist; firm; trims by knife with some difficulty; sand in fine grain; core lengths up to 12".<br>266.9-275.0 SHALE: Medium gray; moist; firm; trims by knife with some difficulty; plastic; air slacks; core lengths up to 8"; bedding dips about 10°. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, H = Hoyatellite, S = Shot, C = Chain
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (R series): Ex = 1:1-2", Ax = 1:7-8", Bx = 2:3-8", Nx = 3"
Approx. size of core (R series): Ex = 7-8", Ax = 1:1-8", Bx = 1:5-8", Nx = 2:1/8"
Outside dia. of casing (R series): Ex = 1:13/16", Ax = 2:1-8", Bx = 2:7-8", Nx = 3:1/2"
Inside dia. of casing (R series): Ex = 1:1-2", Ax = 1:29/32", Bx = 2:3-8", Nx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 3 OF 3 — HOLE NO DH76-105

## SOIL ANALYSES OF DRILL CORE

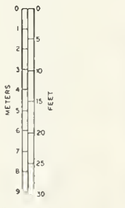
| Lab Number | Boring Number | Depth in feet | Field Texture | Particle Size Analysis % Sand, dia. in mm: 2.0 to 0.1 Vc | 0.5 to 0.25 Co | 0.5 to 0.25 Me | 0.25 to 0.10 Fine | 0.10 to 0.05 Vfine | % Silt | % Clay | Lab Texture | Moisture Retention % Pressure in Bars: 0.10 | 0.33 | 16. | Hyd Cond in/hr: 6 Hr | 24 Hr | Sat ml | Vol | pH @ 25 H2O | Ec x10³ @ 25°C | Soluble Extract Cations, me/l: Ca | Mg | Na | K | Cations | Anions, me/l: CO3 | HCO3 | Cl | SO4 | NO3 | SAR | SP | me/100g: Ca | Mg | Na | K | Total Extractable Cations me/100g: Ca | Mg | Na | K | Exchangeable Cations me/100g: Ca | Mg | Na | K | ESP | % Base Sat | Gyp me/100g | Gyp Req me/100g | CEC meq/100g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6867 | 76-105 | 00-430 | | 3.8 | | | | | 63.1 | 33.1 | SiCL | 45.0 | 37.6 | 18.2 | 0.04 | 0.04 | 32 | 81 | 7.8 | 0.70 | 3.4 | 8.78 | 16.12 | 15.43 | 0.87 | 41.20 | 0.00 | 2.08 | 0.96 | 2.11 | 6.45 | 4.4 | 76.4 | 0.67 | 1.23 | 1.18 | 0.07 | | 1.74 | 0.37 | | 0.56 | 0.30 | 2.9 | | 1.5 | -0.8 | 19.2 |
| 8 | | 478-675 | | 2.5 | | | | | 60.9 | 36.6 | SiCL | 47.4 | 40.3 | 21.7 | 0.03 | 0.03 | 33 | 67 | 6.6 | 0.90 | 4.0 | 17.47 | 15.05 | 20.57 | 1.36 | 54.45 | 0.00 | 4.44 | 0.20 | 41.4 | 1.89 | 5.1 | 74.5 | 1.30 | 1.12 | 1.33 | 0.10 | | 2.35 | 0.47 | | 0.82 | 0.37 | 2.8 | | 1.7 | -0.4 | 29.8 |
| 9 | | 803-1135 | | 2.1 | | | | | 59.4 | 38.5 | SiCL | 48.7 | 46.6 | 29.0 | 0.00 | <0.01 | 37 | 75 | 7.1 | 0.50 | 2.2 | 7.73 | 5.79 | 10.70 | 1.18 | 25.40 | 0.40 | 5.80 | 0.12 | 1.83 | 2.60 | 4.1 | 83.3 | 0.65 | 0.49 | 0.90 | 0.10 | | 1.65 | 0.76 | | 0.75 | 0.66 | 2.2 | | 1.0 | +0.2 | 54.3 |
| 70 | | 1135-1355 | | 45.4 | | | | | 31.3 | 23.3 | L | 31.9 | 22.7 | 11.4 | 0.02 | 0.02 | 30 | 7.9 | 7.3 | 0.46 | 3.1 | 11.08 | 8.05 | 17.00 | 1.23 | 37.36 | 0.00 | 3.20 | 0.68 | 34.15 | <0.02 | 5.5 | 60.5 | 0.56 | 0.41 | 0.86 | 0.06 | | 1.13 | 0.23 | | 0.27 | 0.17 | 2.3 | | 0.6 | -0.4 | 11.9 |
| 1 | | 1335-1750 | | 18.6 | | | | | 47.3 | 34.1 | SiCL | 36.3 | 29.8 | 17.7 | 0.00 | 0.00 | 38 | 84 | 7.6 | 0.34 | 1.6 | 2.47 | 1.81 | 12.43 | 0.69 | 17.40 | 0.16 | 4.68 | 0.16 | 1.41 | <0.02 | 3.5 | 62.8 | 0.16 | 0.11 | 0.78 | 0.04 | | 1.83 | 0.39 | | 1.05 | 0.35 | 6.4 | | 1.3 | +0.4 | 16.3 |
| 2 | | 1750-1850 | | 11.5 | | | | | 25.1 | 63.4 | C | 46.0 | 38.3 | 25.1 | 0.00 | 0.01 | 36 | 62 | 5.7 | 1.2 | 5.0 | 25.80 | 20.48 | 27.57 | 1.36 | 75.21 | 0.00 | 1.76 | 0.16 | 7.00 | 0.09 | 5.7 | 71.1 | 1.83 | 1.46 | 1.96 | 0.10 | | 3.22 | 0.61 | | 1.26 | 0.51 | 8.9 | | 2.2 | -0.4 | 32.4 |
| 3 | | 2045-2296 | | 12.7 | | | | | 53.6 | 31.7 | SiCL | 36.7 | 29.6 | 16.9 | 0.00 | 0.00 | 38 | 83 | 7.4 | 0.24 | 1.2 | 1.43 | 1.09 | 10.83 | 0.56 | 13.91 | 0.40 | 6.16 | 0.08 | 6.50 | 0.02 | 9.6 | 54.0 | 0.09 | 0.06 | 0.58 | 0.06 | | 1.65 | 0.34 | | 1.07 | 0.28 | 8.8 | | 0.6 | +0.8 | 12.2 |
| 6874 | | 2570-2750 | | 4.0 | | | | | 47.3 | 48.7 | SiC | 42.7 | 34.8 | 20.7 | 0.00 | 0.00 | 50 | 85 | 7.6 | 0.46 | 2.1 | 3.62 | 2.44 | 14.74 | 0.84 | 21.64 | 0.16 | 4.20 | 0.68 | 4.86 | 0.02 | 8.5 | 72.3 | 0.26 | 0.18 | 1.07 | 0.06 | | 2.17 | 0.58 | | 1.10 | 0.52 | 5.5 | | 0.7 | +1.1 | 19.9 |

## TRACE ELEMENT ANALYSES OF DRILL CORE [1]

(ppm)

| Lab Number | B | Co | Cu | Fe | Mg | Mn | Mo | Ni | Pb | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6867 | 0.9 | 0.08 | 3.4 | 26.6 | <0.05 | 25.4 | <0.5 | 1.2 | 2.6 | 0.016 | 2.4 |
| 8 | 1.9 | 0.28 | 8.4 | 124.0 | <0.05 | 20.0 | <0.1 | 8.6 | 7.3 | 0.044 | 24.0 |
| 9 | 1.4 | 0.14 | 10.0 | 38.0 | <0.05 | 2.8 | 0.2 | 5.4 | 5.8 | 0.080 | 12.0 |
| 70 | 0.8 | 0.14 | 2.0 | 23.8 | <0.05 | 2.8 | 0.1 | 2.6 | 1.7 | 0.020 | 14.0 |
| 1 | 0.4 | 0.20 | 2.2 | 32.0 | <0.05 | 2.6 | 0.2 | 3.6 | 4.0 | 0.032 | 14.0 |
| 2 | 3.1 | 0.54 | 19.2 | 36.0 | <0.05 | 4.8 | 0.9 | 8.2 | 7.7 | 0.053 | 48.0 |
| 3 | 0.9 | 0.22 | 2.2 | 50.0 | <0.05 | 3.0 | 0.2 | 4.6 | 5.1 | 0.065 | 12.0 |
| 6874 | 0.8 | 0.18 | 7.6 | 40.0 | <0.05 | 1.2 | 0.3 | 3.0 | 6.0 | 0.200 | 20.0 |

[1] Trace analyses determined the presence of these elements available to plants. Standard and accepted methods of extraction and analysis were used. They are listed in Exhibit 3.




Depth on logs in feet
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH 76-105

GEOLOGY G. J. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH, 1977 — SHEET 1 OF 1 — 1305-600-128

# GEOLOGIC LOG OF DRILL HOLE

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming
HOLE NO.: 76-107 — LOCATION: 2010' S, & 660' E, of NW Corner, Sec. 22, T. 56 N., R. 73 W. — Alternate GROUND ELEV: 4188± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8/2/76 — FINISHED: 8/16/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 401.0 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 165.0' 8/16/76 (4023.0') — LOGGED BY: Teucher — LOG REVIEWED BY:

SHEET 1 OF 4

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR CHEMICAL TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole started 8/2/76. Ne drive samples 0 to 12.3'. Hq wireline core 12.3 to 31.8'. Set 6" Cw to 10.0'. 100I drill water return. | | 68 | | | | | | | | | | FT. UNION FORMATION - PALEOCENE: 0-26.4 SHALE: Tan & oxidized 0 to 26.4' black, broken coal 26.4 to 27.3'; medium gray 27.3 to 71.0'; medium to dark gray & carbonaceous 71.0 to 73.6'; dry, becoming moist with depth; moderately firm becoming firm below 27.0'; trims by knife with some difficulty; slight to moderate HCl reaction 0 to 71.0'; no HCl reaction 71.0 to 73.6'; occasional gypsum crystal 0 to 17.0'; very silty (silty shale) 0 to 14.0'; very plastic 14.0 to 73.6'; silty, fine grain sandstone 30.0 to 31.8'; very hard, calcareous siltstone (scratches with knife) 59.4 to 60.5'; 70° joint at 24.0, 25.5 & 62.2'; core lengths 1 to 18" (average 6"). |
| | 10 | 86 | | | | | | | | | | |
| | | 100 | #1 0 | 26.4 | | | | | | | | |
| | | 75 | | | | | | | | | | |
| Hole at 31.8' 8/3/76. 6" Cw at 10.0'. W.L. at 33.6'. Hq wireline core 31.8 to 92.6'. 100I drill water return. | 20 | | | | | | | | | | | |
| | | 100 | | | | | | | | | | |
| | | 56 | | | | | | | | | | 73.6-86.1 SILTY SANDSTONE: Light gray; moist; fine grain, uncemented; crumbles easily between fingers; contains up to 3% silt; soft sandy siltstone 81.5 to 82.0'; pulverized by drilling. |
| Hole at 92.6' 8/4/76. 6" Cw at 30.0'. W.L. at 36.3'. Washed out core in hole from 72 to 92.6'. Hq wireline core 92.6 to 128.6'. 100I drill water return. Using revert. Core dropping from barrel. | | | #2 27.3 | 73.6 | | | | | | | | 86.1-130.3 SHALE: Medium gray 84.1 to 112.0'; medium to dark gray & slightly carbonaceous 112.0 to 121.9'; dark gray & carbonaceous 121.9 to 130.3'; moist, firm; difficult trimming by knife; approaching claystone below 123.0'; bedding not readily discernible; air slacks; slight HCl reaction 84.1 to 121.0'; no HCl reaction 121.0 to 130.3'; broken along 80 to 90° joints 105.0 to 107.0'; two opposing 45° slickensides at 110.8'; very hard, cemented siltstone 110.6 to 110.9' & 113.0 to 114.0'; 70° joint at 114.8'; 1" coal at 115.9'; 45° joint at 124.6'; 90° joint at 126.6 to 128.6'; core lengths 3 to 18". |
| | 30 | 92 | | | | | | | | | | |
| | | 80 | | | | | | | | | | |
| | 40 | | | | | | | | | | | |
| | | 100 | | | | | | | | | | |
| | 50 | | | | | | | | | | | |
| | | 100 | | | | | | | | | | |
| | 60 | | | | | | | | | | | |
| | | 100 | | | | | | | | | | |
| | 70 | | | | | | | | | | | |
| | | 100 | | | | | | | | | | |
| | | | #3 73.6 | 84.1 | | | | 4114.4 | 73.6 | | | 130.3-165.0 COAL: Black; moist; dull; broken; not viable for inspection as coal was bagged & sampled in field. |
| | 80 | 58 | | | | | | | | | | 165.0-176.0 SILTY SANDSTONE: Dark gray & carbonaceous 165.0 to 166.0'; medium gray 166.0 to 176.0'; moist; firm; difficult trimming by knife; plastic; air slacks; 30° slickensides at 172.0, 172.8 & 175.0'; broken in 1 to 3" pieces. |
| | | 69 | | | | | | 4103.9 | 84.1 | | | |
| | 90 | | | | | | | | | | | 176.0-187.0 SILTY TO CLAYEY SANDSTONE: Light gray; moist; uncemented but firm; contains about 30% silt with trace of clay; will not crush between fingers; breaks in fine grain; core lengths 1 to 3". |
| | | 41 | #4 86.1 | 130.3 | | | | | | | | |

* Zone 0 to 14.0 ft. probably WASATCH PM. - EOCENE

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hayrattlins, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series): Ex = 1:1/2", Ax = 1:7/8", Bx = 2:3/8", Nx = 3"
Approx. size of core (X series): Ex = 7/8", Ax = 1:1/8", Bx = 1:5/8", Nx = 2:1/8"
Outside dia. of casing (X series): Ex = 1:13/16", Ax = 2:1/4", Bx = 2:7/8", Nx = 3:1/2"
Inside dia. of casing (X series): Ex = 1:1/2", Ax = 1:29/32", Bx = 2:3/8", Nx = 3"

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 1 OF 4 — HOLE NO. 76-107

# GEOLOGIC LOG OF DRILL HOLE

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming
HOLE NO.: 76-107 — LOCATION: 2010' S, & 660' E, of NW Corner, Sec. 22, T. 56 N., R. 73 W. — Alternate GROUND ELEV: 4188± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8/2/76 — FINISHED: 8/16/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 401.0 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 165.0' 8/16/76 (4023.0') — LOGGED BY: Teucher — LOG REVIEWED BY:

SHEET 2 OF 4

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR CHEMICAL TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 128.6' 8/5/76. 6" Cw at 10.0'. W.L. at 64.6'. Hq wireline core 128.6 to 166.1'. 50I water loss at 140'. Mixed heavy bentonite & pumped into hole. 18' of core in hole at start of shift. | | 99 | | | | | | | | | | 187.0-215.5 SILTY SANDSTONE & SILTY SHALE: Alternating laminations of light gray, uncemented, fine grain silty sandstone & medium gray, firm, moderately plastic silty shale; trims easily with knife; moist; contains about 60% shale & 40% sandstone; more sandy 187.0 to 193.5'; bedding horizontal at 187.0'; dips 5° at 196.0'; 10° at 210', & 5° at 215.0'; breaks along bedding on 1 to 8" centers. |
| | 110 | | | | | | | | | | | |
| | | 90 | | | | | | | | | | |
| | 120 | | | | | | | | | | | |
| | | 100 | | | | | | | | | | |
| Hole at 166.1' 8/6/76. 6" Cw at 10.0'. W.L. at 63.0'. Washed out 30' of core in hole at start of shift. Hq wireline core 166.1 to 201.6'. 80I drill water loss | | 100 | | | | | | | | | | 215.4-279.3 SHALE WITH SANDSTONE: Shale is light to dark gray, firm, plastic, and air slacks; sandstones are fine grain, light gray, silty to clayey & generally weakly cemented; moist; core lengths 1 to 12". |
| | 130 | 96 | | | | | | 4057.7 | 131.0 | | | 215.4-225.8 - Medium gray plastic shale; air slacks; breaks along numerous slickensides 203.8 to 205.8'; light gray clayey siltstone 220.4 to 221.4'. |
| | | 100 | | | | | | | | | | 225.8-226.7 - Weakly cemented, fine grain silty sandstone. |
| | 140 | | | | | | | | | | | 226.7-235.0 - Plastic shale; light to medium gray 226.7 to 228.7 & 230.5 to 235.0'; dark gray & carbonaceous 228.7 to 230.5'; air slacks; numerous slickensides 228.7 to 230.5'. |
| | | 96 | | | | | | | | | | 235.0-242.0 - Light gray, weakly cemented very fine grain silty sandstone; trace of clay; bedding not discernible; will not crush between fingers slight to moderate HCl reaction. |
| Hole at 201.6' 8/9/76. 6" Cw at 10.0'. W.L. at 137.2'. Did not drill. Unable to get water through core barrel. | 150 | | | | | | | | | | | 242.0-259.5 - Light to dark gray plastic shale; carbonaceous 251.0 to 252.2'; slightly carbonaceous 256.2 to 259.5'; slickensides 251.0 to 252.2'; 90° joint 251.8 to 256.0'; scattered slickensides 256.2 to 258.0'; weakly cemented, fine grain silty to clayey sandstone 245.0 to 246.5'. |
| | | 100 | | | | | | 4023.0 | 165.0 | | | 259.5-261.8 - Moderately cemented, light gray, hard silty sandstone; scratches with knife. |
| | 160 | | | | | | | | | | | 261.8-279.3 - Medium to dark gray, slightly carbonaceous shale; firm; air slacks; soft; uncemented siltstone 264.5 to 264.7'; very hard, siliceous siltstone 271.5 to 272.2'; 30 to 70° slickensides on 3" to 1' centers below 273.0'; bedding dips at 5°. |
| | | 100 | | | | | | | | | | |
| | 170 | 20 | #5 165.0 | 176.0 | | | | 4012.0 | 176.0 | | | 279.3-284.9 SILTY SANDSTONE AND SILTY SHALE: Alternating laminations of light gray, uncemented, fine grain silty sandstone (crushes easily between fingers) & soft, moderately plastic silty shale (cuts easily with knife); breaks along 50 bedding planes core lengths 1 to 3". |
| | | 82 | | | | | | | | | | |
| | 180 | | #6 176.0 | 187.0 | | | | | | | | |
| | | 74 | | | | | | 4001.0 | 187.0 | | | |
| | 190 | | | | | | | | | | | |
| | | 100 | #7 187.0 | 215.4 | | | | | | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hayrattlins, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series): Ex = 1:1/2", Ax = 1:7/8", Bx = 2:3/8", Nx = 3"
Approx. size of core (X series): Ex = 7/8", Ax = 1:1/8", Bx = 1:5/8", Nx = 2:1/8"
Outside dia. of casing (X series): Ex = 1:13/16", Ax = 2:1/4", Bx = 2:7/8", Nx = 3:1/2"
Inside dia. of casing (X series): Ex = 1:1/2", Ax = 1:29/32", Bx = 2:3/8", Nx = 3"

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 2 OF 4 — HOLE NO. 76-107

# GEOLOGIC LOG OF DRILL HOLE

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming
HOLE NO.: 76-107 — LOCATION: 2010' S, & 660' E, of NW Corner, Sec. 22, T. 56 N., R. 73 W. — Alternate GROUND ELEV: 4188± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8/2/76 — FINISHED: 8/16/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 401.0 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 165.0' 8/16/76 (4023.0') — LOGGED BY: Teucher — LOG REVIEWED BY:

SHEET 3 OF 4

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR CHEMICAL TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 201.6' 8/10/76. 6" Cw at 10.0'. W.L. at 115.5'. Hq wireline core 201.6 to 242.0'. Washed out 30' of core at start of shift. 70I drill water return. | | 63 | | | | | | | | | | 286.9-327.1 SHALE: Medium to dark gray; moist; firm; difficult trimming by knife; moderately carbonaceous; plastic air slacks; laminated light gray silty, fine grain sandstone & sandy siltstone 291.7 to 293.2'; hard, cemented claystone 298.3 to 299.2' & 302.0 to 302.2'; coal 303.2 to 303.4'; cut by 35 to 50° slickensides on 1 to 6" centers 284.9 to 318.0'; several slickensides 326.6 to 327.1'; less broken below 318.0'; core lengths 1 to 12". |
| | 210 | | | | | | | | | | | |
| | | 65 | | | | | | | | | | |
| | | 100 | | | | | | 3972.9 | 215.4 | | | |
| | 220 | | | | | | | | | | | |
| | | 100 | #8 215.4 | 235.0 | | | | | | | | 327.1-331.9 COAL: Black; wet; dull; broken; not viable for inspection as coal was sampled and bagged in field. |
| | | 92 | | | | | | | | | | |
| | 230 | | | | | | | | | | | |
| | | 78 | | | | | | | | | | 331.9-335.1 SILTY SHALE & SILTY SANDSTONE: Alternating laminations of low plasticity, medium gray silty shale & light gray, very fine grain silty sandstone (approaching siltstone); moist; trims easily by knife; few carbonaceous streaks 331.9 to 333.2'; core lengths 1 to 6". |
| Hole at 242.0' 8/11/76. 6" Cw at 10.0'. W.L. at 136.0'. Washed out 5' of core in hole. Hq wireline core 242.0 to 302.0'. 80I drill water return. | 240 | | | | | | | | | | | |
| | | 76 | #9 235.0 | 242.0 | | | | | | | | |
| | 250 | | | | | | | | | | | |
| | | 100 | | | | | | | | | | |
| | 260 | | #10 242.0 | 279.3 | | | | | | | | 335.1-348.2 COAL: Black; wet; dull; broken; not viable for inspection as coal was sampled and bagged in field. |
| | | 45 | | | | | | | | | | |
| | 270 | | | | | | | | | | | 348.2-353.1 SHALE: Medium gray 348.2 to 351.8'; dark gray & carbonaceous 351.8 to 353.1'; moist; firm; air slacks; trims by knife with difficulty; plastic broken in 1" pieces. |
| | | 100 | | | | | | 1908.7 | 279.3 | | | |
| | 280 | | | | | | | | 285.0 | | | |
| | | 90 | #11 279.3 | 284.9 | | | | 1903.1 | 284.9 | | | 353.1-378.2 COAL: Black; wet; dull; broken; not viable for inspection as coal was sampled & bagged in field. |
| | | 93 | | | | | | | | | | |
| | 290 | | | | | | | | | | | 378.2-401.0 SILTY SHALE: Light gray; moist; firm; difficult trimming by knife; moderately plastic to plastic; slight to moderate HCl reaction; some air slacking; more plastic below 396.0' cemented, hard silty sandstone 388.6 to 389.1'; core lengths up to 12". |
| | | 93 | | | | | | | | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hayrattlins, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series): Ex = 1:1/2", Ax = 1:7/8", Bx = 2:3/8", Nx = 3"
Approx. size of core (X series): Ex = 7/8", Ax = 1:1/8", Bx = 1:5/8", Nx = 2:1/8"
Outside dia. of casing (X series): Ex = 1:13/16", Ax = 2:1/4", Bx = 2:7/8", Nx = 3:1/2"
Inside dia. of casing (X series): Ex = 1:1/2", Ax = 1:29/32", Bx = 2:3/8", Nx = 3"

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 3 OF 4 — HOLE NO. 76-107

# GEOLOGIC LOG OF DRILL HOLE

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming
HOLE NO.: 76-107 — LOCATION: 2010' S, & 660' E, of NW Corner, Sec. 22, T. 56 N., R. 73 W. — Alternate GROUND ELEV: 4188± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8/2/76 — FINISHED: 8/16/76 — DEPTH OF OVERBURDEN: -- — TOTAL DEPTH: 401.0 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 165.0' 8/16/76 (4023.0') — LOGGED BY: Teucher — LOG REVIEWED BY:

SHEET 4 OF 4

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR CHEMICAL TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 302.0' 8/12/76. 6" Cw at 10.0'. W.L. at 135.5'. Washed out 100' of core in hole. Hq wireline core 302.0 to 350.0'. 60I drill water return 302.0 to 363.0'. 30I drill water return 363.0 to 350.0'. | | 94 | #12 286.9 | 327.1 | | | | | | | | |
| | 310 | | | | | | | | | | | |
| | | 91 | | | | | | | | | | |
| | 320 | 98 | | | | | | | | | | |
| Hole at 350.0' 8/13/76. 6" Cw at 10.0'. W.L. at 155.8'. Washed out 160' of core in hole. Hq wireline core 350.0 to 401.0'. 20I drill water return in coal zones. | | 100 | | | | | | 3860.9 | 327.1 | | | |
| | 330 | 100 | | | | | | | | | | |
| | | 100 | #13 331.9 | 335.1 | | | | 3856.1 | 331.9 | | | |
| | | 100 | | | | | | 3852.9 | 335.1 | | | |
| Hole at 401.0' 8/16/76. 6" Cw at 10.0'. W.L. at 165.0'. Washed hole to bottom for geophysical logging. Core down rig & moved equipment. | 340 | | | | | | | | | | | |
| | 350 | 67 | #14 348.2 | 353.1 | | | | 3839.8 | 348.2 | | | |
| | | 98 | | | | | | 3834.9 | 353.1 | | | |
| | 360 | | | | | | | | | | | |
| | | 99 | | | | | | | | | | |
| | 370 | | | | | | | | | | | |
| | | 60 | | | | | | 3809.8 | 378.2 | | | |
| | 380 | | | | | | | | | | | |
| | | 81 | #15 378.2 | 401.0 | | | | | | | | |
| | 390 | | | | | | | | | | | |
| | | 77 | | | | | | | | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hayrattlins, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series): Ex = 1:1/2", Ax = 1:7/8", Bx = 2:3/8", Nx = 3"
Approx. size of core (X series): Ex = 7/8", Ax = 1:1/8", Bx = 1:5/8", Nx = 2:1/8"
Outside dia. of casing (X series): Ex = 1:13/16", Ax = 2:1/4", Bx = 2:7/8", Nx = 3:1/2"
Inside dia. of casing (X series): Ex = 1:1/2", Ax = 1:29/32", Bx = 2:3/8", Nx = 3"

FEATURE: White Tail Butte Study Site, Little Powder River Coal Field — PROJECT: EMRIA No. 13 — STATE: Wyoming — SHEET 4 OF 4 — HOLE NO. 76-107

## SOIL ANALYSES OF DRILL CORE

| Lab Number | Boring Number | Depth in Inches | Field Texture | Particle Size Analysis % Sand, dia. in mm 2.0-1.0 V.Co | 1.0-0.5 Co | 0.5-0.25 Med | 0.25-0.10 Fine | 0.10-0.05 V.Fine | % Silt | % Clay | Lab Test | Moisture Retention % Pressure in Bars 0.10 | 0.33 | 15. | Hyd Cond. in/hrs 6 Hr. | 24 Hr. | Set ml | Vol in | pH @ 25 °C H2O | CaCl2 | Sp. Gr. g/cm³ 25°C | Saturation Extract Cations, me/l Ca | Mg | Na | K | Cations | Anions, me/l CO3 | HCO3 | Cl | SO4 | NO3 | SAR | SP | me/100g Ca | Mg | Na | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6803 | 76-107 | 0.0-26.4 | | 7.0 | | | | | 58.6 | 34.2 | SiCL | 37.7 | 32.9 | 17.2 | 0.07 | 0.08 | 2.9 | 8.0 | 7.6 | 1.4 | 5.5 | 24.20 | 38.57 | 25.43 | 1.27 | 89.47 | 0.00 | 1.68 | 3.12 | 78.1 | .19 | 4.5 | 70.2 | 1.69 | 2.71 | 1.79 | 0.09 |
| 4 | | 27.8-73.6 | | 1.0 | | | | | 61.7 | 37.1 | SiCL | 43.4 | 36.9 | 21.6 | 0.04 | 0.05 | 34 | 8.3 | 7.5 | 0.40 | 1.7 | 4.17 | 4.16 | 16.17 | 0.90 | 19.40 | 0.24 | 7.72 | 0.00 | 11.2 | <.002 | 5.0 | 73.8 | 0.31 | 0.31 | 0.75 | 0.07 |
| 5 | | 73.6-84.1 | | 54.6 | 0.1 | 0.2 | 0.2 | 31.6 | 22.5 | 29.0 | 16.4 | FSL | 23.5 | 21.7 | 7.2 | 0.19 | 0.16 | 2.0 | 8.1 | 7.3 | 0.30 | 1.7 | 6.99 | 6.15 | 9.52 | 0.97 | 23.99 | 0.16 | 5.48 | 0.54 | 17.7 | <.002 | 3.7 | 42.1 | 0.23 | 0.27 | 0.40 | 0.04 |
| 6 | | 84.1-130.3 | | 2.7 | | | | | | 56.2 | 41.1 | SiC | 45.1 | 38.7 | 24.9 | 0.02 | 0.04 | 35 | 8.3 | 7.1 | 0.40 | 1.7 | 3.30 | 4.25 | 11.09 | 0.90 | 20.14 | 0.24 | 9.88 | 0.24 | 8.74 | <.002 | 5.5 | 73.5 | 0.23 | 0.31 | 0.82 | 0.07 |
| 7 | | 165.0-176.0 | | 5.1 | | | | | | 41.2 | 53.7 | SiC | 42.1 | 34.6 | 20.5 | 0.00 | 0.00 | 55 | 8.7 | 7.6 | 0.32 | 1.3 | 0.77 | 0.63 | 1.57 | 0.38 | 13.35 | 0.40 | 5.28 | 0.00 | 6.38 | <.002 | 14. | 76.3 | 0.06 | 0.05 | 0.88 | 0.03 |
| 8 | | 176.0-187.0 | | 26.0 | | | | | | 47.6 | 26.4 | L | 34.1 | 29.1 | 11.9 | 0.00 | 0.00 | 45 | 8.9 | 7.8 | 0.24 | 1.3 | 0.77 | 0.63 | 1.43 | 0.38 | 13.21 | 0.40 | 4.96 | 0.04 | 7.64 | <.002 | 14. | 51.8 | 0.04 | 0.03 | 0.59 | 0.02 |
| 9 | | 187.0-215.5 | | 9.2 | | | | | | 55.4 | 35.2 | SiCL | 37.4 | 31.5 | 17.5 | 0.00 | 0.00 | 55 | 9.0 | 7.7 | 0.25 | 1.1 | 0.60 | 0.45 | 0.96 | 0.36 | 12.37 | 0.40 | 5.96 | 0.36 | 5.56 | <.002 | 15. | 61.9 | 0.04 | 0.03 | 0.68 | 0.02 |
| 10 | | 215.4-279.3 | | 1.1 | | | | | | 32.7 | 46.2 | SiC | 39.9 | 33.5 | 18.4 | 0.00 | 0.00 | 60 | 8.1 | 7.6 | 0.26 | 1.2 | 0.44 | 0.27 | 9.59 | 0.28 | 10.58 | 0.32 | 4.36 | 0.00 | 5.54 | <.002 | 16. | 80.1 | 0.04 | 0.02 | 0.75 | 0.02 |
| 11 | | 279.3-284.9 | | 23.9 | | | | | | 48.8 | 27.3 | CL | 31.0 | 26.2 | 19.9 | 0.00 | 0.00 | 42 | 9.1 | 7.9 | 0.26 | 1.2 | 0.60 | 0.36 | 1.06 | 0.36 | 11.93 | 0.24 | 4.36 | 1.08 | 6.52 | <.002 | 15. | 53.4 | 0.03 | 0.02 | 0.54 | 0.02 |
| 12 | | 284.9-327.1 | | 4.9 | | | | | | 57.1 | 43.0 | SiC | 37.4 | 31.2 | 17.2 | 0.26 | 0.98 | 60 | 8.7 | 7.7 | 0.26 | 0.98 | 0.62 | 0.41 | 9.91 | 0.43 | 13.79 | 0.43 | 5.04 | 0.00 | 9.34 | <.002 | 14. | 71.7 | 0.06 | 0.05 | 0.85 | 0.03 |
| 13 | | 327.1-343.9 | | 22.8 | | | | | | 46.0 | 31.2 | CL | 33.0 | 26.2 | 19.7 | 0.00 | 0.00 | 42 | 8.6 | 7.6 | 0.16 | 1.5 | 1.92 | 1.90 | 14.43 | 0.63 | 18.88 | 0.16 | 3.48 | 0.72 | 14.57 | 0.34 | 18. | 53.0 | 0.10 | 0.10 | 0.77 | 0.03 |
| 14 | | 343.9-327.1 | | 3.1 | | | | | | 55.3 | 42.4 | C | 41.7 | 35.2 | 12.7 | 0.00 | 0.00 | 45 | 7.9 | 6.2 | 0.30 | 4.0 | 14.17 | 13.40 | 25.48 | 1.40 | 54.95 | 0.00 | 1.68 | 0.12 | 58.7 | 0.07 | 0.5 | 8.9 | 0.56 | 1.5 | 2.18 | 0.12 |
| 6985 | | 378.2-401.0 | | 10.3 | | | | | | 54.5 | 35.2 | SiCL | 31.3 | 26.1 | 12.7 | 0.00 | 0.00 | 50 | 8.4 | 7.1 | 0.82 | 1.7 | 2.67 | 2.44 | 14.35 | 0.85 | 20.33 | 0.08 | 4.00 | 0.60 | 18.05 | 0.08 | 10. | 54.7 | 0.15 | 0.13 | 0.78 | 0.05 |

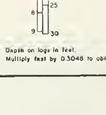
| Lab Number | Total Extractable Cations me/100g Ca | Mg | Na | K | Exchangeable Cations me/100g Ca | Mg | Na | K | ESP | % Base Sat | Gyp me/100g | Gyp Req | CEC me/100g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6803 | 2.00 | 0.33 | | | 0.21 | 0.30 | 1.2 | | | 45 | -3.8 | 16.8 | 17.1 |
| 4 | 1.48 | 0.46 | | | 0.73 | 0.39 | 3.5 | | | 50 | 0.0 | 20.8 | 20.0 |
| 5 | 0.78 | 0.17 | | | 0.38 | 0.13 | 4.2 | | | 37 | -0.4 | 9.0 | 10.0 |
| 6 | 1.65 | 0.49 | | | 0.83 | 0.42 | 3.6 | | | 50 | 0.0 | 23.5 | 23.0 |
| 7 | 3.48 | 0.62 | | | 2.60 | 0.59 | 12. | | | 15 | +1.9 | 22.3 | 20.0 |
| 8 | 2.00 | 0.31 | | | 1.41 | 0.29 | 12. | | | 28 | +0.8 | 17.2 | 14.0 |
| 9 | 2.70 | 0.43 | | | 2.02 | .41 | 13. | | | 30 | +1.6 | 14.0 | 0.0 |
| 10 | 3.13 | 0.56 | | | 2.58 | 0.54 | 13. | | | 06 | +2.5 | 18.1 | 0.3 |
| 11 | 1.83 | 0.29 | | | 1.29 | 0.27 | 12. | | | 08 | +1.5 | 10.9 | |
| 12 | 2.78 | 0.48 | | | 1.73 | 0.42 | 12. | | | 13 | +1.4 | 16.7 | 0.0 |
| 13 | 1.65 | 0.38 | | | 0.86 | 0.35 | 6.1 | | | 06 | +0.4 | 14.2 | |
| 14 | 3.13 | 0.68 | | | 0.75 | 0.56 | 4.6 | | | 11 | +1.0 | 23.5 | |
| 6985 | 1.56 | 0.42 | | | 0.79 | 0.37 | 4.9 | | | 08 | +0.6 | 16.1 | |

## TRACE ELEMENT ANALYSES OF DRILL CORE 1/

(ppm)

| Lab Number | B | Co | Cu | Fe | Hg | Mn | Mo | Ni | Pb | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6803 | 0.7 | 0.06 | 3.0 | 26.2 | 0.0059 | 14.2 | <0.5 | 1.2 | 5.6 | 0.008 | 2.6 |
| 4 | 0.0 | 0.08 | 5.8 | 122.0 | 0.11 | 16.4 | <0.5 | 5.2 | 5.0 | 0.020 | 8.0 |
| 5 | 0.0 | 0.16 | 2.0 | 54.0 | 0.047 | 8.4 | <0.5 | 2.4 | 5.4 | 0.006 | 5.0 |
| 6 | 0.3 | 0.24 | 6.6 | 108.0 | 0.047 | 15.6 | <0.5 | 7.0 | 7.0 | 0.020 | 10.0 |
| 7 | 0.0 | 0.14 | 4.4 | 32.0 | 0.038 | 0.4 | <0.5 | 2.4 | 8.0 | 0.021 | 10.0 |
| 8 | 0.4 | 0.12 | 2.4 | 30.0 | 0.047 | 0.4 | <0.5 | 2.8 | 4.8 | 0.016 | 8.0 |
| 9 | 1.2 | 0.16 | 3.2 | 31.0 | 0.049 | 1.2 | <0.5 | 3.0 | 5.0 | 0.021 | 14.0 |
| 10 | 0.2 | <0.5 | 4.0 | 6.2 | 0.049 | 5.8 | | | | | |
| 11 | | | | | | | | | | | |
| 12 | 0.4 | <0.5 | 3.4 | 7.0 | 0.024 | 10.0 | | | | | |
| 13 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 6985 | | | | | | | | | | | |

1/ These analyses determined the ppm of these elements available to plants. Standard and accepted methods of extraction and analyses were used. They are listed in Exhibit 3.




Depth on logs in feet. Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH 76-107

GEOLOGY: G. J. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:

BILLINGS, MONTANA — MARCH, 1977 — SHEET 1 OF 1 — 1305-600-130

T-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 11

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO. 76-108 — LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W. — Altimeter GROUND ELEV 4188± — DIP (ANGLE FROM HORIZ) Vertical
BEGUN 10/5/76 — FINISHED 4/6/77 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 785.5 — BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED ..... — LOGGED BY Taucher to 359.7' — LOG REVIEWED BY

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Boile analysis barrels: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole started 10/5/76. Set up rig. No drive samples 0 to 9.0'. Hq wireline core 9.0 to 26.0'. Set 6" pipe to 9.0'. Hole at 24.0' 10/6/76. 6" Cs at 9.0'. W.L. at 16.5'. Hq wireline core 24.0 to 94.0'. 100% drill water loss at 80.0'. | | 60 | | | | | | | | | | FT. UNION FORMATION - PALEOCENE<br>0-16.5 SHALE: Tan & oxidized 0 to 12.0'; tan to gray & slightly oxidized 12.0 to 16.5'; moist; moderately firm 0 to 12.0'; becoming more firm 12.0 to 16.5'; trims by knife; bedding not readily discernible; plastic; air slacks; active HCl reaction 0 to 5.0' (no core 5.0 to 9.0'); slight to moderate HCl reaction 9.0 to 16.5'; ½" gypsum-lined bedding plane at 16.0'; core length 3 to 12". |
| | | 0 | #1 0 21.5 | 16.5 & 24.3 | | | | | | | | |
| | | 90 | | | | | | | | | | |
| | | 45 | | | | | | 4171.5 | 16.5 | | | |
| | | | | | | | | 4166.5 | 21.5 | | | 16.5-21.5 SANDSTONE: Tan; uncemented; washed away during drilling. |
| | | | | | | | | 4163.7 | 24.3 | | | |
| Hole at 94.0' 10/7/76. 6" Cs at 9.0'. W.L. at 92.0'. Hq wireline core 94.0 to 134.0'. 100% drill water loss. Used 3200 gallons of water. | | 95 | #2 24.3 minus siltstone 35.7 | 41.5 | | | | | | | | 21.5-24.3 SHALE: Dark gray; moist; firm; trims easily by knife; bedding not readily discernible; plastic; air slacks; laminated, slightly oxidized medium gray silty shale & clayey siltstone 21.5 to 22.5'; 3 to 12" core lengths. |
| | | 85 | | | | | | 4146.5 | 41.5 | | | 24.3-41.5 SILTY SHALE WITH SILTSTONE: Alternating laminations of medium gray, moderately plastic silty shale & light gray, uncemented clayey to sandy siltstone (70% shale & 30% siltstone); moderately firm; cuts easily by knife; moist; oxidized 34.7 to 35.7'; very hard, calcareous siltstone 35.7 to 38.5'; bedding near horizontal; core lengths 1 to 8". |
| | | | #3 41.5 | 50.0 | | | | | | | | |
| | | 100 | | | | | | 4138.0 | | | | |
| | | 60 | #4 50.0 | 70.0 | | | | | | | | 41.5-50.0 SILTY SANDSTONE: Tan; slightly oxidized; moist; uncemented; generally pulverized by drilling; laminated where structure hasn't been destroyed; very fine grain; uniform; 15% silt; scattered (5%) silty shale streaks up to 1" thick. |
| | | | | | | | | 4118.0 | | | | 50.0-70.0 SHALE: Medium gray & slightly laminated 50.0 to 55.0'; dark gray grading to black with depth 55.0 to 70.0'; carbonaceous; moist; very firm; difficult trimming by knife; near clay-stone; bedding not readily apparent below 55.0'; plastic; air slacks; very slight HCl reaction in zones; broken coal 53.5 to 54.0'; core lengths 1 to 18". |
| | | 100 | | | | | | | | | | 70.0-100.5 COAL: Black; moist; not visible for inspection as coal was bagged and sampled in field. |
| | | 100 | | | | | | | | | | 100.5-104.5 SHALE & COAL: Black; moist; firm; trims by knife with difficulty; shattered by slickensides; air slacks |

ANDERSON SEAM

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystaflite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1:1/2" Ax = 1:7/8" Bx = 2:3/8" Nx = 3"
Approx. size of core (X-series) Ex = 7/8" Ax = 1:1/8" Bx = 1:5/8" Nx = 2:1/8"
Outside dia. of casing (X-series) Ex = 1:13/16" Ax = 2:1/4" Bx = 2:7/8" Nx = 3:1/2"
Inside dia. of casing (X-series) Ex = 1:1/2" Ax = 1:29/32" Bx = 2:3/8" Nx = 3"

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 1 OF 11 — HOLE NO 76-108

T-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 11

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO 76-108 — LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W. — Altimeter GROUND ELEV 4188± — DIP (ANGLE FROM HORIZ) Vertical
BEGUN 10/5/76 — FINISHED 4/6/77 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 785.5 — BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED ..... — LOGGED BY Taucher to 359.7' — LOG REVIEWED BY

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Boile analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 134.0' 10/8/76. 6" Cs at 9.0'. W.L. at 95.5'. Hq wireline core 134.0 to 154.0'. Driller reported uncemented sandstone washed away 144.0 to 154.0'. Total water loss. Used 1600 gallons of water. Returned to duty station. | | 100 | | | | | | 4087.5 | 100.5 | | | badly; highly carbonaceous; approaching coal in zones; broken coal 103.5 to 104.5'; core lengths under 3". |
| | | 100 | | | | | | 4083.5 | 104.5 | | | 104.5-135.5 SILTY TO SANDY SHALE: Light to medium gray; moist; varies from thin-bedded & laminated to almost mottled in appearance; material is generally silty to sandy shale but contains laminations of light gray siltstone or very fine grain sandstone; shale trims easily with knife; sandstone & siltstone is uncemented & crushes between fingers; slightly to moderately plastic; plasticity decreasing with depth; scattered marcasite or pyrite nodules up to ½" in diameter developed in sandy zones or along bedding planes; upper part contains about 70% shale & 30% siltstone & sandstone; lower part contains about 50% shale & 50% siltstone & sandstone; 50° joint at 118.6'; scattered carbonaceous fragments; core lengths 1 to 6". |
| Hole at 154.0' 10/12/76. 6" Cs at 9.0'. W.L. at 95.0'. Returned from duty station. Hole caved at 95.0' Washed out hole. | | 85 | #5 104.5 | 135.5 | | | | | | | | |
| Hole at 154.0' 10/13/76. 6" Cs at 9.0'. W.L. at 95.0'. Hole caved at 97.0'. Washed out hole. Hq wireline core 154.0 to 214.0'. Driller reported uncemented sandstone washing away 154.0 to 200'. | | 100 | #6 135.5 | 144.0 | | | | 4052.5 | 135.5 | | | 135.5-144.0 SILTY SANDSTONE WITH SILTY SHALE: Alternating laminations of light gray, uncemented, silty, fine grain sandstone (crushes between fingers) & low plasticity, medium gray, moderately firm silty shale (cuts easily with knife); sandstone is about 60% of material; moist; begins to wash away during drilling; core lengths 1 to 6". |
| | | 65 | | | | | | 4044.0 | 144.0 | | | 144.0-174.0 SANDSTONE: Very little core recovered; driller reported sandstone, probably fine grain & uncemented. |
| | | 0 | | | | | | | | | | 174.0-177.5(?) SHALEY SANDSTONE OR SANDY SHALE: Medium to dark gray; moist; firm; trims by knife with some difficulty; moderately plastic when reworked; appears cross-bedded; slightly carbonaceous. |
| | | 3 | | | | | | 4014.0 | 174.0 | | | |
| | | 0 | | | | | | 4010.5 | 177.5 | | | 177.5-200.0 SILTY SANDSTONE: Core recovered is light gray; moist; uncemented; crushes easily between fingers; fine grain; contains about 15% silt; scattered silty shale & carbonaceous silty sandstone laminations; contains marcasite and/or pyrite nodules; washes away during drilling. |
| | | 70 | | | | | | | | | | |
| | | 15 | #7 177.5 Probably not a representative sample. 200.0 | | | | | | | | | |
| | | 40 | | | | | | 988.0 | 200.0 | | | 200.0-254.0 SHALE: Medium to dark gray; moist; generally firm & difficult to trim by knife; soft & cuts easily by knife 213.0 to 224.0 & 228.0 to 234.0'; slightly carbonaceous; cut by numerous slickensides between 204.0 & 214.0'; |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystaflite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1:1/2" Ax = 1:7/8" Bx = 2:3/8" Nx = 3"
Approx. size of core (X-series) Ex = 7/8" Ax = 1:1/8" Bx = 1:5/8" Nx = 2:1/8"
Outside dia. of casing (X-series) Ex = 1:13/16" Ax = 2:1/4" Bx = 2:7/8" Nx = 3:1/2"
Inside dia. of casing (X-series) Ex = 1:1/2" Ax = 1:29/32" Bx = 2:3/8" Nx = 3"

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 2 OF 11 — HOLE NO 76-108

T-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 11

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO 76-108 — LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W. — Altimeter GROUND ELEV 4188± — DIP (ANGLE FROM HORIZ) Vertical
BEGUN 10/5/76 — FINISHED 4/6/77 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 785.5 — BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED ..... — LOGGED BY Taucher to 359.7' — LOG REVIEWED BY

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Boile analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 214.0' 10/14/76. 6" Cs at 9.0'. W.L. at 93.0'. Washed core from hole below 95.0'. Hq wireline core 214.0 to 254.0'. Used 3200 gallons of water. | | 85 | | | | | | | | | | plastic; air slacks; hard; cemented (siliceous) siltstone 208.2 to 209.8'; sandy 200.0 to 202.0'; pyrite 202.0 to 202.2'; bedding not readily discernible core lengths 6 to 18". |
| Hole at 254.0' 10/15/76. 6" Cs at 93.0' Gressed rig. Returned to duty station | | 70 | #8 200.0 | 254.0 | | | | | | | | 254.0-260.0 SHALE: Medium to dark gray & slightly carbonaceous 254.0 to 256.0'; dark gray to black & carbonaceous below 256.0'; moist; very firm; trims by knife with difficulty; plastic; numerous irregular slickensides 256.0 to 260.0'; air slacks; 1 to 6" core lengths. |
| 10/18/76 - Returned from duty station. Did not go to drill; rig because of icy roads. | | 90 | | | | | | | | | | 260.0-263.5 COAL: Black; wet; not visible for inspection as coal was sampled & bagged in field. |
| Hole at 254.0' 10/19/76. 6" Cs at 9.0'. W.L. at 93.8'. Hq wireline core 254.0 to 283.5'. Took 3½ hours to wash core from hole. Used 3200 gallons of water. | | 95 | | | | | | | | | | 263.5-269.5 SILTSTONE: Light to medium gray; moist; laminated; slightly carbonaceous; trace of clay & fine sand; slightly plastic; crumbles between fingers with difficulty; slight HCL reaction; core lengths 2 to 6". |
| | | 100 | | | | | | | | | | 269.5-282.9 COAL: Black; wet; not visible for inspection as coal was sampled & bagged in field. |
| Hole at 283.5' 10/20/76. 6" Cs at 9.0'. W.L. at 93.8'. Washed core from hole below 110.0'. Hq wireline core 283.5 to 322.5'. Used 4000 gallons of water. | | 95 | #9 263.5 | 269.5 | | | | | | | | 282.9-299.5 SILTSTONE WITH SILTSTONE & SANDSTONE: Light to medium gray; moist; firm; difficult trimming by knife; banded to laminated in places; moderately plastic to plastic; air slacks. 282.9-299.5 - Silty shale with slightly cemented sandstone streaks 289.5 to 289.9'. 299.5-303.5 - Alternating laminations of medium gray plastic shale & light gray clayey siltstone & silty sandstone; scattered pyrite nodules along bedding planes. 303.5-307.5 - Medium gray shale becoming dark gray & carbonaceous with depth. |
| Hole at 322.5' 10/21/76. Repairs made on hydraulic line. | | 75 | | | | | | | | | | |
| Hole at 322.5' 10/26/76. Repairs made on rig. Hole at 322.5' 10/27/76. 6" Cs at 9.0'. W.L. at 95.3'. Washed out core from hole. Used 4000 gallons of water. | | 56 | | | | | | | | | | 307.5-329.0 COAL: Black; wet; not visible for inspection as coal was sampled & bagged in field. |
| | | 90 | #10 282.9 | 307.5 | | | | | | | | 329.0-341.5 SHALE: Medium gray; moist; soft to moderately firm; cuts easily with knife; plastic; bedding not readily discernible; air slacks; becoming silty shale with carbonaceous seams 329.0 to 334.5'; numerous slickensides 334.5 to 335.5'; core lengths 3 to 18". |
| | | 85 | | | | | | | | | | 341.5-346.0 Driller reported SILTY SANDSTONE with pyrite nodules. Most of |

DIETZ

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystaflite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1:1/2" Ax = 1:7/8" Bx = 2:3/8" Nx = 3"
Approx. size of core (X-series) Ex = 7/8" Ax = 1:1/8" Bx = 1:5/8" Nx = 2:1/8"
Outside dia. of casing (X-series) Ex = 1:13/16" Ax = 2:1/4" Bx = 2:7/8" Nx = 3:1/2"
Inside dia. of casing (X-series) Ex = 1:1/2" Ax = 1:29/32" Bx = 2:3/8" Nx = 3"

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 3 OF 11 — HOLE NO 76-108

T-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 11

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming
HOLE NO 76-108 — LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W. — Altimeter GROUND ELEV 4188± — DIP (ANGLE FROM HORIZ) Vertical
BEGUN 10/5/76 — FINISHED 4/6/77 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 785.5 — BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED ..... — LOGGED BY Taucher to 359.7' — LOG REVIEWED BY

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Boile analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 322.5' 10/28/76. 6" Cs at 9.0'. W.L. at 95.6'. Hq wireline core 322.5 to 340.0'. Ground up 3.5' of core trying to recover. Used 2400 gallons of water. Set Nx Cs to 340.0'. | | 100 | | | | | | | | | | sample washed away during drilling. Samples recovered consisted of alternating laminations of uncemented silty sandstone & silty shale with scattered pyrite inclusions. |
| Hole at 340.0' 10/29/76. 6" Cs. Nx Cs at 340.0'. Broke down Hq rods. Brought "old" water truck to Billings, Montana. | | 100 | | | | | | 3880.5 | 307.5 | | | CANYON |
| 11/1/76 - Changed cooks on water trucks. Got swine flu shots. Returned to Broadus. | | 65 | #11 329.0 | 341.5 | | | | 3859.0 | 329.0 | | | 346.0-350.5 SHALE: Black; moist; very firm; near claystone; air slacks; highly carbonaceous; trims by knife with difficulty; bedding not readily discernible. |
| Hole at 340.0' 11/2/76. 6" Cs at 9.0'. Nx Cs at core 340.0 to 370.0'. Losing 10% drill water. Core loss due to uncemented sandstone zones washing away. | | 95 | | | | | | 3846.5 | 341.5 | | | 350.5-354.0 SILTY SANDSTONE & SILTY SHALE: Alternating laminations of medium to dark gray, plastic silty to sandy shale & light gray, uncemented, fine grain silty sandstone; moist; trims easily by knife; scattered pyrite nodules generally lying along bedding planes; 50% shale 350.5 to 352.5 & 353.4 to 354.0'; 30% shale 352.5 to 353.4'. |
| | | 40 | | | | | | 3842.0 | 346.0 | | | 354.0-359.7 SHALE: Dark gray; moist; firm; trims by knife with difficulty; carbonaceous; approaching claystone; air slacks; plastic when reworked. |
| Hole at 370.0' 11/3/76. 6" Cs at 9.0'. Nx Cs at 340.0'. W.L. at 95.6'. Nx core 370.0 to 411.0'. Pulled drill rods to check drill bit. Losing 20% water. Mixed 2 pits of bentonite. | | 100 | | | | | | 3837.5 | 350.5 | | | 359.7-361.2 SHALE: Medium-dark gray; silty; laminated in places; slickensides, stems & branches; hard; carbonaceous in places; becoming more carbonaceous in bottom 0.4'. |
| | | 100 | | | | | | 3834.0 | 354.0 | | | |
| | | 81 | | | | | | 3828.3 | 359.7 | | | 361.2-365.3 COAL: Hard; black; slickensides 363.0 to 365.3'; becoming shaley 365.0 to 365.3'. |
| | | 86 | | | | | | | | | | 365.3-367.4 SHALE: Medium-dark gray; silty in places; hard; stems & leaves; slickensides 365.3-365.5'; interlaminated with sand 365.9-366.3'; sand is very fine grained; light gray & mottled in appearance with shale. |
| | | 100 | | | | | | | | | | 367.4-373.2 SHALE: Light-medium gray; firm; stems & leaves; becomes more thinly divided near bottom; silty; interlaminated with sand 367.4-370.0; sand is very fine grained, light gray, soft & uncemented with wavy bedding; bedding less common below 369.5'; no HCl reaction 367.4 to 369.2'; slight HCl reaction at 369.3'; strong HCl reaction at 370.0'; no HCl reaction 370.0 to 371.0'; very slow HCl reaction 371.0 to 372.5'; no HCl reaction 372.5 to 373.2'; scattered slickensides 367.4 to 370.0'; trims easily with knife; gradational upper and lower contacts. |
| | | 100 | | | | | | | | | | |
| | | 80 | | | | | | | | | | |

COOK ZONE

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystaflite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1:1/2" Ax = 1:7/8" Bx = 2:3/8" Nx = 3"
Approx. size of core (X-series) Ex = 7/8" Ax = 1:1/8" Bx = 1:5/8" Nx = 2:1/8"
Outside dia. of casing (X-series) Ex = 1:13/16" Ax = 2:1/4" Bx = 2:7/8" Nx = 3:1/2"
Inside dia. of casing (X-series) Ex = 1:1/2" Ax = 1:29/32" Bx = 2:3/8" Nx = 3"

FEATURE White Tail Butte Study Site — Little Powder River Coal Field — PROJECT EMRIA No. 13 — STATE Wyoming — SHEET 4 OF 11 — HOLE NO 76-108

## SOIL ANALYSES OF DRILL CORE

| Lab Number | Boring Number | Depth in Inches | Field Texture | Particle Size Analysis: % Sand, dia in mm 2.0-1.0 VCo | 1.0-0.5 Co | 0.5-0.25 Med | 0.25-0.10 Fine | 0.10-0.05 VFine | % Silt | % 2μ Clay | Lab Text | Moisture Retention: % Pressure in Bars 0.10 | 0.33 | 15 | Hyd Cond in/hrs 6 Hr | 24 Hr | Set ml | pH @ 25 $H_2O$ 1:5 | $CaCl_2$ | $E_{xp}\times10^3$ @ 25°C | $E_{xp}\times10^3$ @ 25°C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6986 | 76-108 | 0.0-16.5 | | 2.2 | | | | | 57.4 | 40.4 | SiC | 45.8 | 38.8 | 20.6 | <0.01 | <0.01 | 35 | 7.8 | 7.6 | 0.52 | 5.5 |
| 7 | | 243-415 | | 7.0 | | | | | 61.2 | 31.8 | SiCL | 41.4 | 34.0 | 15.0 | <0.01 | <0.01 | 23 | 8.0 | 7.2 | 0.38 | 1.8 |
| 8 | | 415-50.0 | | 65.1 | 0.1 | 0.2 | 0.3 | 19.2 | 45.3 | 20.1 | VFSL | 26.5 | 18.3 | 5.9 | 0.14 | 0.14 | 20 | 8.1 | 7.4 | 0.34 | 2.3 |
| 9 | | 50.0-70.0 | | 1.2 | | | | | 55.8 | 43.0 | SiC | 44.6 | 37.5 | 25.3 | <0.01 | <0.01 | 34 | 7.9 | 6.6 | 0.48 | 2.8 |
| 90 | | 104.5-135.5 | | 12.7 | | | | | 48.7 | 38.6 | SiCL | 46.5 | 38.7 | 19.4 | <0.01 | <0.01 | 35 | 8.1 | 7.5 | 0.30 | 1.8 |
| 1 | | 135.5-140.0 | | 41.2 | | | | | 35.2 | 23.6 | L | 33.5 | 24.0 | 12.5 | <0.01 | 0.02 | 24 | 7.9 | 7.4 | 0.30 | 1.9 |
| 2 | | 177.5-200.0 | | 23.6 | | | | | 41.7 | 34.7 | CL | 37.4 | 29.1 | 13.5 | <0.01 | <0.01 | 29 | 7.6 | 7.1 | 0.36 | 1.8 |
| 3 | | 220.0-254.0 | | 1.3 | | | | | 35.4 | 63.3 | C | 41.3 | 34.5 | 23.4 | <0.01 | <0.01 | 48 | 8.2 | 7.4 | 0.34 | 1.5 |
| 4 | | 282.0-307.5 | | 4.5 | | | | | 57.3 | 38.2 | SiCL | 35.5 | 28.6 | 18.8 | <0.01 | <0.01 | 48 | 7.9 | 7.3 | 0.24 | 1.3 |
| 6995 | | 329.0-341.5 | | 1.4 | | | | | 34.4 | 64.2 | C | 40.7 | 35.1 | 24.0 | <0.01 | <0.01 | 63 | 8.1 | 7.3 | 0.50 | 1.9 |

| Lab Number | Saturation Extract: Cations, me/l Ca | Mg | Na | K | Anions, me/l Cl | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | SAR | SP | me/100g Ca | Mg | Na | K | Total Extractable Cations me/100g Ca | Mg | Na | K | Exchangeable Cations me/100g Ca | Mg | Na | K | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6986 | 7.45 | 33.47 | 17.57 | 1.64 | 4.13 | 0.00 | 2.40 | 1.20 | 44.95 | 0.23 | 31 | 84.9 | 2.16 | 3.53 | .49 | .14 | .10 | -0.2 | 23.7 | 0.3 | 0.34 | 6.6 | 108.0 | 0.098 | 0.4 | 0.5 | 3.4 | 7.0 | 7.0 | 0.020 | 10.0 |
| 7 | 8.43 | 8.14 | 5.04 | 1.18 | 12.77 | 0.08 | 4.88 | 0.32 | 17.80 | 0.09 | 1.8 | 67.6 | 0.59 | 0.57 | 0.35 | 0.08 | 0.43 | 0.47 | | 0.08 | 0.39 | 0.4 | | 1.0 | -0.7 | 19.4 | 0.0 | 0.14 | 4.4 | 32.0 | 0.038 | 0.4 | 0.5 | 2.4 | 8.0 | 0.021 | 10.0 |
| 8 | 10.98 | 7.15 | 10.89 | 0.77 | 16.27 | 0.00 | 2.32 | 1.04 | 18.52 | 0.10 | 3.3 | 46.9 | 0.51 | 0.43 | 0.49 | 0.04 | 0.61 | 0.17 | | 0.12 | 0.13 | 1.5 | | 0.8 | -0.7 | 7.74 | 0.4 | 0.12 | 2.4 | 30.0 | 0.047 | 0.3 | 0.5 | 2.8 | 4.8 | .16 | 8.0 |
| 9 | 11.03 | 9.87 | 12.39 | 1.59 | 36.88 | 0.16 | 7.80 | 0.40 | 12.42 | 0.15 | 3.8 | 62.5 | 0.76 | 0.68 | 0.05 | 0.11 | 1.48 | 0.76 | | 0.63 | 0.65 | 2.3 | | 0.9 | +0.1 | 27.5 | 0.0 | 0.16 | 3.2 | 36.0 | 0.049 | 1.2 | 0.5 | 3.0 | 5.0 | 0.021 | 4.0 |
| 90 | 4.12 | 2.80 | 10.57 | 1.07 | 18.50 | 0.24 | 3.72 | 0.20 | 15.53 | 0.12 | 5.7 | 63.8 | 0.26 | 0.18 | 0.67 | 0.07 | 1.48 | 0.69 | | 0.81 | 0.62 | 4.5 | | 0.5 | +1.1 | 17.9 | 0.3 | 0.08 | 5.8 | 32.0 | 0.072 | 0.2 | 0.5 | 5.4 | 6.2 | 0.049 | 5.8 |
| 1 | 9.93 | 8.14 | 4.39 | 1.57 | 24.03 | 0.08 | 3.84 | 0.48 | 15.33 | 0.10 | 1.5 | 60.0 | 0.60 | 0.41 | 0.26 | 0.09 | 1.13 | 0.44 | | 0.37 | 0.38 | 4.7 | | 0.4 | +0.5 | 12.2 | | | | | | | | | | |
| 2 | 1.90 | 1.19 | 0.74 | 16.70 | 0.40 | 4.12 | 0.00 | 1.48 | 0.10 | 7.7 | 85.1 | 0.21 | 0.16 | 0.75 | 0.06 | 0.35 | | | | 0.56 | 0.55 | | | 0.8 | -0.6 | 8.1 | 0.0 | 0.12 | 5.4 | 40.0 | 0.098 | 0.4 | 0.5 | 3.4 | 7.0 | 0.026 | 10.0 |
| 3 | 1.15 | 0.90 | 0.40 | 0.57 | 13.10 | 0.40 | 5.00 | 0.08 | 7.14 | 0.08 | 0.4 | 62.4 | 0.07 | 0.06 | 0.66 | 0.04 | 2.40 | 0.79 | | 1.49 | 0.73 | 5.9 | | 0.9 | +1.8 | 25.3 | 0.0 | 0.02 | 0.4 | 19.2 | 0.016 | 15.0 | 0.5 | 0.4 | 2.0 | 0.003 | 2.6 |
| 4 | 1.35 | 2.86 | 18.8 | <0.01 | <0.01 | 0.40 | 7.9 | 7.3 | 0.24 | .13 | 1.5 | 0.70 | 0.40 | 0.57 | 13.10 | 0.40 | 0.91 | 0.43 | | 0.91 | 0.43 | 5.6 | | 0.6 | +1.1 | 16.1 | 0.0 | 0.04 | 1.6 | 25.8 | 0.053 | 7.2 | 0.5 | 0.6 | 2.0 | 0.003 | 1.2 |
| 6995 | 3.78 | 2.89 | 14.61 | 0.96 | 22.19 | 0.32 | 4.12 | 0.08 | 18.22 | 0.10 | 2.0 | 69.4 | 0.33 | 0.26 | 1.31 | 0.09 | 2.70 | 0.82 | | 1.39 | 0.73 | 6.2 | | 0.8 | +1.3 | 22.3 | 2.0 | 0.32 | 5.2 | 116.0 | 0.011 | 44.2 | 0.6 | 8.6 | 4.6 | 0.026 | 26.0 |

## TRACE ELEMENT ANALYSES OF DRILL CORE 1/

(ppm)

| Lab Number | Boring Number | Depth in Inches | % Base Sat | Gyp me/100G | Gyp Req me/100G | CEC me/100G | pH Sat | K | Co | Cu | Fe | Hg | Mn | Mo | Ni | Pb | Se | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6986 | 76-108 | 0.0-16.5 | | .10 | -0.2 | 23.7 | 0.3 | 0.34 | 6.6 | 108.0 | 0.098 | 15.6 | 0.5 | 7.0 | 7.0 | 0.020 | 10.0 | |
| 7 | | 243-415 | | .10 | -0.7 | 19.4 | 0.0 | 0.14 | 4.4 | 32.0 | 0.038 | 0.4 | 0.5 | 2.4 | 8.0 | 0.021 | 10.0 | |
| 8 | | 415-50.0 | | .08 | -0.7 | 7.74 | 0.4 | 0.12 | 2.4 | 30.0 | 0.047 | 0.3 | 0.5 | 2.8 | 4.8 | .16 | 8.0 | |
| 9 | | 50.0-70.0 | | .09 | +0.1 | 27.5 | 0.0 | 0.16 | 3.2 | 36.0 | 0.049 | 1.2 | 0.5 | 3.0 | 5.0 | 0.021 | 4.0 | |
| 90 | | 104.5-135.5 | | .05 | +1.1 | 17.9 | 0.3 | 0.08 | 5.8 | 32.0 | 0.072 | 0.2 | 0.5 | 5.4 | 6.2 | 0.049 | 5.8 | |
| 1 | | 135.5-140.0 | | .04 | +0.5 | 12.2 | | | | | | | | | | | | |
| 2 | | 177.5-200.0 | | .08 | -0.6 | 8.1 | 0.0 | 0.12 | 5.4 | 40.0 | 0.098 | 0.4 | 0.5 | 3.4 | 7.0 | 0.026 | 10.0 | |
| 3 | | 220.0-254.0 | | .09 | +1.8 | 25.3 | 0.0 | 0.02 | 0.4 | 19.2 | 0.016 | 15.0 | 0.5 | 0.4 | 2.0 | 0.003 | 2.6 | |
| 4 | | 282.0-307.5 | | .06 | +1.1 | 16.1 | 0.0 | 0.04 | 1.6 | 25.8 | 0.053 | 7.2 | 0.5 | 0.6 | 2.0 | 0.003 | 1.2 | |
| 6995 | | 329.0-341.5 | | .08 | +1.3 | 22.3 | 2.0 | 0.32 | 5.2 | 116.0 | 0.011 | 44.2 | 0.6 | 8.6 | 4.6 | 0.026 | 26.0 | |

1/ These analyses determined the ppm of these elements available to plants. Standard and accepted methods of extraction and analyses were used. They are listed in Exhibit 3.

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECREATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD, WYOMING

# GEOLOGIC LOG OF DH 76-108

GEOLOGY G. J. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH, 1977 — SHEET 1 OF 3

1305-600-13

7-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 5 OF 11

FEATURE White Tail Butte Study Site
Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO. 76-108
LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W.
Alitemeter
GROUND ELEV. 4188±
DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/5/76 FINISHED 4/6/77
DEPTH OF OVERBURDEN --
TOTAL DEPTH 785.5
BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
LOGGED BY Goolsby (USGS)
LOG REVIEWED BY

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Bulk analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 411.0' 11/4/76. 6" Cs at 9.0'. Nx Cs at 340.0'. W.L. at 118.0'. Washed out core & cuttings from hole. Nx wireline core 411.0 to 421.0'. Repairs on pump. Returned to duty station. | 410 | 97 | | | | | | 3787.0<br>3784.8 | 401.0<br>402.2 | | | 373.2-374.0 SANDSTONE: Very fine grained to fine grained; light to medium gray; uncemented; laminated; wavy bedding; crushes easily between fingers; interbedded with medium gray, moderately firm shale which trims by knife; shale is soft & plastic in places; a few stem & leaf fragments; probable core loss in sandstone; rapid gradational lower contact. |
| 11/8/76 - Returned from duty station. Serviced rig. W.L. at 118.3'. | 420 | 85 | | | | | | 3778.5<br>3776.4<br>3774.9<br>3774.5<br>3772.7<br>3772.3 | 409.5<br>411.5<br>413.1<br>413.5<br>415.3<br>415.7 | | | 374.0-375.8 SHALE: Carbonaceous; black; firm; trims easily by knife; conchoidal to even fractures; no apparent bedding; several low angle slickensides 375.6 to 375.8'; sharp lower contact. |
| Hole at 421.0' 11/9/76. 6" Cs at 9.0'. Nx Cs at 340.0'. W.L. below 300'. Nx wireline core 421.0 to 450.0'. Losing 90% of water (Used 2400 gallons of water). Took 3 hours to flush core & cuttings from hole prior to caving. | 430 | 94 | | | | | | 3767.9<br>3767.0<br>3766.2 | 420.0<br>421.0<br>421.8 | | | 375.8-381.3 SHALE: Medium-dark gray; firm; trims easily by knife; stem & leaves; sand laminations 375.8 to 377.3'; sand is very fine grained, medium gray, soft, uncemented & silty; shale is silty to sandy in places 375.8 to 378.2'; scattered low angle slickensides 378.4 to 379.2'; many low angle slickensides 379.2 to 381.3'; grades from dark gray to almost black carbonaceous shale below 379.4'; becomes soft & plastic 381.0 to 381.3'. |
| Hole at 450.0' 11/10/76. 6" Cs at 9.0'. Nx Cs at 340.0'. W.L. below 200'. Washed out 40' of core in cuttings in hole. Nx wireline core 450.0 to 480.0'. 80% drill water return. Dropped core 470 to 480'. | 440 | 90 | | | | | | 3756.3<br>3755.8<br>3752.6<br>3751.6 | 430.7<br>431.2<br>435.4<br>436.4 | | | 381.3-383.1 COAL: Black; hard; moist. |
| Hole at 480.0' 11/11/76. 6" Cs at 9.0'. Nx Cs at 340.0'. Pulled rods & changed bit. Recovered 20% of core from 470 to 480' run. Nx core 480.0 to 482.0'. Sticking tools. Pulled rods. | 450 | 100 | | | | | | 3740.5<br>3740.1<br>3736.8 | 447.5<br>447.9<br>451.2 | | | 383.1-386.2 MUDSTONE: Medium-dark gray; soft; firm; moderately plastic to plastic; scattered stems & leaves; trims easily by knife; dark gray & carbonaceous 383.1 to 383.3' & 385.9 to 386.2'; silty 385.1 to 385.9'; many scattered slickensides. |
| 11/12 & 11/15 - Moved pipe & equipment to Broadus. | 460 | 80 | | | | | | | | | | 386.2-388.1 COAL: Black; hard; moist. |
| 11/16/76 - Cleaned hole for geophysical logging by USGS. | 470 | 20 | | | | | | 3707.6<br>3706.0 | 480.0<br>482.0 | | | 388.1-392.5 SHALE: Medium-dark gray; firm; thinly divided stem & leaf fragments; trims easily by knife; dark gray with many slickensides 388.1 to 388.4'; medium gray & silty 388.4 to 391.9'; dark gray with many slickensides 391.9 to 392.5'; scattered slickensides 389.2 to 391.9'; becomes carbonaceous 391.9 to 392.5'. |
| | 480 | 90 | | | | | | | | | | 392.5-393.6 COAL: Black; hard; moist. |
| | | 63 | | | | | | | | | | 393.6-393.8 SHALE: Dark gray; carbonaceous; firm; stem & leaf fragments; slickensides; trims easily by knife. |
| | 490 | 80 | | | | | | 3692.4<br>3690.4 | 495.6<br>497.6 | | | 393.8-399.6 SANDSTONE: Fine grained to |
| | | 100 | | | | | | | | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, H = Haystaliite, S = Shot, C = Chun
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sections) Ex = 1-1/2", As = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sections) Ex = 7/8", As = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sections) Ex = 1-13/16", As = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sections) Ex = 1-1/2", As = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE White Tail Butte Study Site
Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 5 OF 11 HOLE NO. 76-108

7-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 6 OF 11

FEATURE White Tail Butte Study Site
Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO. 76-108
LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W.
Alitemeter
GROUND ELEV. 4188±
DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10-5-76 FINISHED 4/6/77
DEPTH OF OVERBURDEN --
TOTAL DEPTH 785.5
BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
LOGGED BY Goolsby (USGS)
LOG REVIEWED BY

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Bulk analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/12/77 - Moved rig to site. Broke trail through snow drifts. | | 95 | | | | | | | | | | very fine grained; medium gray; soft; uncemented; crushes easily by fingers; wavy bedding; interbedded with light-medium gray, firm, sandy to silty shale; trims easily by knife; stem & leaf fragments; sharp, even upper and lower contacts; loss probably in sandstone around 395.4'. |
| Hole at 482.0' 1/13/77. 6" Cs at 9.0'. NxCs at 340.0'. Washing out hole with drill rods. Unable to reach bottom due to caving. Stuck rods. Used 3200 gallons of water. | 510 | 50 | | | | | | 3676.2 | 510<br>517.4 | | | 399.6-401.0 MUDSTONE: Dark gray; firm; horizontal slickensides; coal laminations; carbonaceous stem & leaf fragments; becomes silty below 400.9'; trims easily by knife; slight HCl reaction below 400.9'. |
| 1/14/77 - Recovered drill rods. Heavy snow. Returned to Billings. | 520 | 80 | | | | | | | 520 | | | 401.0-402.2 SILTSTONE: Light gray; firm; reacts readily with HCl; stem & leaf fragments; shaley in places; gradational upper & lower contacts. |
| 1/17/77 - Returned to drill site. Unable to reach site due to snowdrifts. Stuck water truck. | 530 | 95 | | | | | | | 530 | | | 402.2-409.5 SANDSTONE: Fine grained; light-medium gray; soft; uncemented; crushes easily between fingers; stem & leaf fragments; interbedded to interlaminated with medium gray, firm, moderately plastic mudstone; scattered horizontal slickensides; stem & leaf fragments; trims easily by knife. |
| 1/18/77 - Plowed road to rig & pulled out water truck. Hole at 482.0' | 540 | 50 | | | | | | 3642.7<br>3641.6<br>3641.0 | 545.3<br>546.4<br>547.0 | | | 409.5-409.8 SHALE: Dark gray to black; carbonaceous; firm; many slickensides; moderately plastic; becomes progressively more carbonaceous with depth. |
| 1/19/77. 6" Cs at 9.0'. NxCs at 340.0'. Pulled NxCs & reamed hole with 4¾" drag bit to 340.0'. Used 3200 gallons of water. | 550 | 90 | | | | | | 3630.0<br>3629.3<br>3627.8 | 558.0<br>558.7<br>560.2 | | | 409.8-411.6 COAL: Black; hard; moist. |
| Hole at 482.0' 1/20/77. 6" Cs at 9.0'. Reamed hole with 4¾" drag bit 340.0 to 480.0'. Pulled rods. Unable to set NxCs below 280.0' due to caving. Used 3200 gallons of water. | 560 | 100<br>100 | | | | | | | | | | 411.6-413.1 SHALE: Dark gray; soft; plastic; carbonaceous in places; many slickensides; trims with knife. |
| | 570 | 91<br>200 | | | | | | | | WALL | | 413.1-413.5 COAL: Badly broken; black; moist. |
| | | 0 | | | | | | 3614.7<br>3614.2 | 573.3<br>573.8 | | | 413.5-415.3 SHALE: Dark gray to black; firm to soft; moderately plastic to plastic; carbonaceous; scattered horizontal slickensides. |
| Hole at 482.0' 1/21/77. 6" Cs at 9.0'. NxCs at 280.0'. Washed & pushed (hydraulic) NxCs to 480.0'. Hole squeezing. Returned to Billings, Montana. | 580 | 67 | | | | | | 3608.5 | 579.5<br>580 | | | 415.3-415.7 COAL: Badly broken; black; moist. |
| | | 100<br>100<br>80 | | | | | | 3604.0<br>3603.0 | 584.0<br>585.0 | | | 415.7-420.1 SHALE: Light to medium gray; firm; trims by knife; silty in places; stem & leaf fragments; scattered slickensides; dark gray & carbonaceous 415.7 to 415.9'; medium gray, with many slickensides 418.8 to 419.2'; gradational lower contact. |
| | 590 | 67 | | | | | | 3595.5 | 590<br>592.5 | | | |
| | | 0 | | | | | | 3588.1 | 599.9 | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ..... O = Diamond, H = Haystaliite, S = Shot, C = Chun
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sections) Ex = 1-1/2", As = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sections) Ex = 7/8", As = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sections) Ex = 1-13/16", As = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sections) Ex = 1-1/2", As = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE White Tail Butte Study Site
Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 6 OF 11 HOLE NO. 76-108

7-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 7 OF 11

FEATURE White Tail Butte Study Site
Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO. 76-108
LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W.
Alitemeter
GROUND ELEV. 4188±
DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10-5-76 FINISHED 4/6/77
DEPTH OF OVERBURDEN --
TOTAL DEPTH 785.5
BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
LOGGED BY Goolsby (USGS)
LOG REVIEWED BY

| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Bulk analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 482.0' 1/24/77. Returned from duty station. 6" Cs at 9.0'. Nx Cs at 480.0'. Washed cuttings 300.0 to 420.0' from hole. | | 80<br>100 | | | | | | | | | | 420.1-421.0 SILTSTONE: Light gray; sandy; firm; hard; trims by knife; stem & leaf fragments; becomes more sandy near bottom. |
| Hole at 482.0' 1/25/77. 6" Cs at 9.0'. NxCs at 480.0'. Finished washing out hole. Pulled N rods. Nx wire line core 482.0 to 490.0'. | 610 | 78 | | | | | | | 610 | | | 421.0-421.8 SANDSTONE: Fine grained to very fine grained; light gray; uncemented; shaley laminations; soft; crumbles between fingers with difficulty; uncommon fine carbonaceous plant fragments; sharply gradational lower contact. |
| 1/26/77 - Unable to reach rig due to blizzard & drifting snow. | 620 | 90<br>100 | | | | | | 3561.5<br>3561.0 | 626.5<br>627.0 | | | 421.8-431.7 SHALE: Light gray 421.8 to 423.6'; medium gray 423.6 to 425.6'; dark gray 425.6 to 429.3'; medium gray 429.3 to 431.7'; moderately plastic; trims easily by knife; silty 422.7 to 422.8'; fine, carbonaceous plant fragments 421.0 to 425.6'; large, carbonaceous plant fragments 425.6 to 428.3'; fine, carbonaceous plant fragments 429.3 to 431.7'; abundant, randomly oriented slickensides 425.6 to 428.1'; scattered randomly oriented slickensides 428.1 to 431.7'; carbonaceous 425.6 to 428.1'; very fine grained, sandstone laminations 428.7 to 431.7'; gradational lower contact. |
| 1/27/77 - Stuck 4x4 (front end out of 4x4). Used water truck for transportation. Unable to get road plowed. | 630 | 53<br>100 | | | | | | 3554.5<br>3549.5 | 630<br>633.5<br>640 | | | |
| 1/28/77 - Returned to Billings. Worked in warehouse. | 640 | 100 | | | | | | 3550.0<br>3538.4<br>3536.4 | 648.0<br>649.6<br>651.6 | | | 431.7-432.2 SILTSTONE: Medium gray; very hard; will not trim by knife; carbonaceous; plant fragments; contains abundant chert clasts (.01 to .1" in size; angular, tan & coated with a white substance); gradational lower contact. |
| 1/31/77 - Returned to site. Unable to get road plowed until 2:00 p.m. (2 hours plowing). Pulled out stuck 4x4. | 650 | 100 | | | | | | 3531.0<br>3530.4 | 657.0<br>657.6 | | | |
| Hole at 490.0' 2/1/77. 6" Cs at 9.0'. NxCs at 480.0'. Washed hole. Nx wireline core 490.0 to 520.0'. Took 4x4 to Gillette for repairs. Part of core washed away 512.0 to 520.0' (uncemented sandstone.) | 660 | 90 | | | | | | 3523.0 | 660<br>665.0 | | | 432.2-435.4 SHALE: Medium gray; moderately plastic; interlaminated with sandstone; sandstone in very fine grained, light gray, & uncemented; laminations are irregular; tan, fine to coarse grained chert clasts 433.0 to 433.2'; light tan, clay clasts 434.2 to 434.4'; uncommon carbonaceous plant fragments; laminations disrupted am by burrowing or root action in places; gradational lower contact. |
| | 670 | 67<br>19 | | | | | | 3506.7 | 670<br>683 | PAWNEE K | | |
| Hole at 520.0' 2/2/77. 6" Cs at 9.0'. Nx Cs at 480.0'. Nx wireline core 520.0 | 680 | 60 | | | | | | 3501.4 | 686.6 | | | 435.4-436.4 SHALE: Medium-dark gray; moderately plastic to plastic; abundant randomly scattered slickensides; rare carbonaceous plant fragments; carbonaceous 436.0 to 436.4'. |
| | 690 | 90 | | | | | | 3494.8<br>3494.4<br>3492.8<br>3492.5<br>3491.0 | 690<br>693.2<br>693.6<br>695.2<br>695.5<br>697.0 | | | 436.4-447.5 COAL: |
| | | | | | | | | | | | | 447.5-447.9 SHALE: Dark gray-black; crumbles easily; very carbonaceous; abundant, randomly oriented slickensides; coaly in places. |

EXPLANATION

CORE LOSS / CORE RECOVERY

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Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sections) Ex = 1-1/2", As = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sections) Ex = 7/8", As = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sections) Ex = 1-13/16", As = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sections) Ex = 1-1/2", As = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE White Tail Butte Study Site
Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 7 OF 11 HOLE NO. 76-108

7-1337 (5-63)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 8 OF 11

FEATURE White Tail Butte Study Site
Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO. 76-108
LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W.
Alitemeter
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DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
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| Notes on water losses and levels, casing, cementing, caving, and other drilling conditions | Type and size of hole | Core recovery (%) | Bulk analysis sample: Depth (feet) From | To | Suitability for reconstructed profile: Suitable | Limited suitability | Unsuitable | Elev. (feet) | Depth (feet) | Graphic log | Samples for testing | Classification and physical condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| to 563.0'. Losing 50% drill water. Washed away some uncemented sandstone 540 to 550'. | | 60 | | | | | | | | | | 447.9-449.9 COAL: |
| Hole at 563.0' 2/3/77. 6" Cs at 9.0'. Nx Cs at 480.0'. Washed core from hole. Nx wireline core 563.0 to 570.0'. Hole squeezing in coal. 2400 gallons of water used. Pulled rods & changed bit. | 710 | 62<br>100<br>85 | | | | | | | 710 | | | 449.9-451.2 SHALE: Dark gray-black; carbonaceous; moderately plastic; abundant, randomly oriented slickensides; trims easily by knife; sharp lower contact. |
| 2/4/77 - Set rods in hole. Unable to drill to bottom of coal due to squeezing (difficulty turning rods due to squeezing). Returned to duty station. | 720 | 12 | | | | | | 3458.2<br>3457.8<br>3456.5 | 729<br>730<br>731.5 | | | 451.2-480.0 SHALE: Light-medium gray; moderately plastic; soft; trims easily by knife; uncommon scattered carbonaceous plant fragments; abundant, randomly oriented slickensides 452.6 to 456.0'; 458.4 to 463.9', and 467.0 to 468.4'; scattered, randomly oriented slickensides elsewhere; silty & firm 451.2 to 452.6 & 463.9 to 467.0'; carbonaceous shale 462.7 to 462.8'; very fine grained sandstone lamination 465.3'. |
| 2/7/77 - Returned to site. Went to Gillette for 4x4. | 730 | 13 | | | | | | 3449.7<br>3448.0 | 738.3<br>740 | | | 480.0-480.4 SILTSTONE: Trims by knife with difficulty; light tan-gray; strong HCl reaction; vertical slickensides; extremely irregular lower contact with some shale protruding into siltstone. |
| 2/8/77 - Hammered on NxCs. Broke 2 cables & hoisting plug. Unable to pull back NxCs. | 740 | 3 | | | | | | | | | | 480.4-482.0 SHALE: Medium gray; soft; firm; moderately plastic; trims by knife; rare carbonaceous plant fragments; scattered, randomly oriented slickensides; silty 481.6 to 482.0'; very soft 480.4 to 480.9'. |
| 2/9/77 - Hammered on NxCs for 2 hours. Pulled back 5". Broke hoisting plug. Unloaded 8x wireline equipment. | 750 | 0<br>20 | | | | | | 3428.0 | 750<br>760 | | | 482.0-495.6 MUDSTONE: Gray; soft; silty and hard 485.3 to 486.0'. |
| 2/10/77 - Hammered on NxCs for 5 hours. Pulled 4.0'. Set "N" rods in hole. | 760 | 80<br>90 | | | | | | 3423.0<br>3421.4<br>3421.1 | 765.0<br>766.6<br>766.9 | | | 495.6-497.6 SILTSTONE: Light gray; very hard & dense. |
| Hole at 570.0' 2/11/77. 6" Cs at 9.0'. NxCs at 476.0'. Pulled Nx wireline rods & removed barrel. Set Nx wireline rods to 573.0' (Using as casing). Washed hole to 573.0'. Returned to duty station. | 770 | 21 | | | | | | | 770 | CACHE L | | 497.6-511.8 SHALE: Dark gray to black; carbonaceous streaks; some thin sandy zones 500.0 to 500.8' becoming less sandy with more carbonaceous streaks below 502.4'. |
| | 780 | 0 | | | | | | 3406.5<br>3402.5 | 780<br>783.7 | | | 511.8-545.3 SANDSTONE: Light gray to white; very fine grained; very soft; interbedded with black mudstone 524.0 to 524.9'; carbonaceous streaks 533.8 to 538.3'; coal streaks & reworked fragments 539.5, 539.6, 539.7 to 539.9, 541.0 and 541.9'; becomes silty 543.0 to 545.3'. |
| 2/14/77 - Returned to Broadus. | 790 | | | | | | | | 790 | | | 545.3-546.4 MUDSTONE: Black; interbedded with white, very fine grained sandstone. |
| | | | | | | | | | | | | 546.4-547.0 SANDSTONE: White; becoming fine grained. |

EXPLANATION

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Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sections) Ex = 1-1/2", As = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sections) Ex = 7/8", As = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sections) Ex = 1-13/16", As = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sections) Ex = 1-1/2", As = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE White Tail Butte Study Site
Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 8 OF 11 HOLE NO. 76-108

METERS / FEET

Depth on logs in feet
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

# GEOLOGIC LOG OF DH 76-108

GEOLOGY G. J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA SHEET 2 OF 3 MARCH, 1977 1305-600-132

7-1337 (10-69)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 9 OF 11

FEATURE White Tail Butte Study Site Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO 76-108
LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W.
Altimeter
GROUND ELEV 4188±
DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/5/76 FINISHED 4/6/77
DEPTH OF OVERBURDEN --
TOTAL DEPTH 785.5
BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED below 482.0'
LOGGED BY Hobbs (USGS)
LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/15/77 - Washed to bottom of hole. | | | | | | | | | | | | 547.0-550.0 SHALE(?): Lost core. |
| Hole at 573.0' 2/16/77. 6" Cs at 9.0'. NxCs at 476.0'. N wireline rods at 573.0'. 5 hours washing drill mud from hole. Bx wireline core 573.0 to 579.5'. Recovered 2 handfulls of pyrite nodules on top of core. | 10 | | | | | | | | 10 | | | 550.0-558.0 SANDSTONE: Light gray to white; very fine grained; coal inclusions (reworked) at 551.0'; branch (coal) at 552.5 to 553.0'; dark gray mudstone with light gray streaks 554.0 to 555.0'; small coal fragments at 556.7'. |
| Hole at 579.5' 2/17/77. 6" Cs at 9.0'. NxCs at 476.0'. N wireline rods at 573.0'. Bx wireline core 579.5 to 592.5'. Pyrite nodules falling in drill hole (affecting drilling), coring very slow. Set N wireline rods to 585.0' to stop pyrite from falling in hole. | 20 | | | | | | | | 20 | | | 558.0-558.7 MUDSTONE: Gray; soft; twig & branch fragments. |
| | | | | | | | | | | | | 558.7-560.0 SANDSTONE: Gray; very fine to fine-grained; upper 0.3' silty; becoming hard at base; pyrite nodules (0.03' in dia.) in basal sandstone. |
| | 30 | | | | | | | | 30 | | | 560.0-560.2 COAL: Soft; earthy. |
| | | | | | | | | | | | | 560.2-569.5 COAL: Badly broken; bright & dull bands; apparent cleat & buff fractures; coal roof appears to have been cut out. |
| | 40 | | | | | | | | 40 | | | 569.5-570.0 COAL: Thin-bedded; flakey; very soft; some mudstone streaks. |
| | | | | | | | | | | | | 570.0-573.3 COAL: No core (driller). |
| Hole at 592.5' 2/18/77. 6" Cs at 9.0'. NxCs at 476.0'. N wireline rods at 585.0'. Washed hole. Bx wireline core 592.5 to 598.5'. Dropped core. Returned to Billings. | 50 | | | | | | | | 50 | | | 573.3-573.8 - Pyrite nodule zone up to 0.05' in diameter. Matrix more or less washed out; remnants appear to be a soft earthy MUDSTONE. |
| | | | | | | | | | | | | 573.8-579.5 MUDSTONE: Gray to dark gray earthy carbonaceous plant fragments & rootlets (paleosoil horizon?) 579.5'. |
| 2/22/77 - Returned to White Tail Butte. Blizzard conditions. Unable to reach drill rig. | 60 | | | | | | | | 60 | | | 579.5-584.0 SHALE: Black; carbonaceous. |
| | | | | | | | | | | | | 584.0-585.0 - Pyrite nodule zone in gray earthy MUDSTONE (90%: pyrite). Nodules up to 0.05' in diameter. |
| Hole at 598.5' 2/23/77. 6" Cs at 9.0'. NxCs at 476.0'. N wireline rods at 585.0'. Washed hole. Bx wireline core 598.5 to 602.5'. Dropped core. Redrilled & pulled rods. Recovered 3.2' of core (broken). Replaced bit. | 70 | | | | | | | | 70 | | | 585.0-592.5 MUDSTONE: Gray; bedded; carbonaceous (branch & twig); pyrite nodule (up to 0.03' thick) streak at 586.7'. |
| | | | | | | | | | | | | 592.5-599.9 SHALE: No core (driller). |
| | 80 | | | | | | | | 80 | | | 599.9-626.5 CLAYSTONE: Light gray; massive; hard to very hard; highly calcareous (strong HCl reaction); even bedding; dark & medium gray 614.5 to 626.5'. |
| | | | | | | | | | | | | 626.5-627.0 LIMESTONE: Medium gray; very dense and hard. |
| 2/24/77 - Unable to reach drill rig due to blizzard (zero visibility). Returned to Billings. | 90 | | | | | | | | 90 | | | |

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: O = Diamond, H = Hoosteliite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 9 OF 11 HOLE NO 76-108

7-1337 (10-69)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 10 OF 11

FEATURE White Tail Butte Study Site Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO 76-108
LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W.
Altimeter
GROUND ELEV 4188±
DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/5/76 FINISHED 4/6/77
DEPTH OF OVERBURDEN --
TOTAL DEPTH 785.5
BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED
LOGGED BY Hobbs (USGS) below 482.0'
LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/28/77 - Tried to get to drill rig through heavy snow. Broke 4x4 axle. | | | | | | | | | | | | 627.0-633.5 MUDSTONE: Medium gray; even bedded. |
| 3/1/77 - Shoveled road to stuck 4x4 and pulled out with water truck. | 10 | | | | | | | | 10 | | | 633.5-638.5 SILTSTONE: Calcareous; even bedded; crossbedded with carbonaceous material 635.7 to 638.5'. |
| | | | | | | | | | | | | 638.5-648.0 SILTSTONE: Sandy to silty sandstone; very fine to fine grained. |
| 3/2/77 - Waiting for snowplow. | | | | | | | | | | | | 648.0-649.6 MUDSTONE: Gray; becoming more silty towards base; contact with underlying coal is sharp. |
| 3/3/77 - Road plowed near end of day. | 20 | | | | | | | | 20 | | | 649.6-650.6 COAL: Bright and dull bands; hard; appears to have been washed out (channel). |
| Hole at 602.5' 3/4/77. 6" Cs at 9.0'. NxCs at 476.0'. N wireline rods at 585.0'. Washed hole. Bx wireline core 602.5 to 605.5'. Returned to Billings. | 30 | | | | | | | | 30 | | | 650.6-651.6 COAL: Soft; flakey; bottom 0.1' is soft and earthy; brownish cast. |
| 3/7/77 - Returned to Gillette to check on repairs to 4x4. | 40 | | | | | | | | 40 | | | 651.6-657.0 MUDSTONE: Black; earthy; carbonaceous (leaf, branch & twig fragments); paleosoil horizon. |
| | | | | | | | | | | | | 657.0-657.6 MUDSTONE: Light gray; massive. |
| 3/8/77 - Tried to clean hole. Unable to get to bottom. Pulled rods. Set N wireline rods to 590.0'. Washed to bottom of hole with B rods. | 50 | | | | | | | | 50 | | | 657.6-665.0 MUDSTONE: Medium gray; 45° slickenside at 658.0'; carbonaceous (twigs & branches) 661.0 to 663.0'; light gray mudstone at 663.0' grading into very fine grained material at 665.0' |
| | | | | | | | | | | | | 665.0-666.2 COAL(?): No core. |
| | 60 | | | | | | | | 60 | | | 666.2-673.0 COAL: Badly broken; bright & dull bands; hard; poor cleat fractures; bedded pyrite nodule at 672.7' up to 0.05' in diameter. |
| | | | | | | | | | | | | 673.0-681.0 COAL: No core (driller). |
| Hole at 605.5' 3/9/77. NxCs at 476.0' N wireline rods at 590.0'. Bx wireline core 605.5 to 627.0'. | 70 | | | | | | | | 70 | | | 681.0-681.3 COAL: |
| | | | | | | | | | | | | 681.3-681.6 MUDSTONE: Dark gray to black; earthy; much carbonaceous material. |
| Hole at 627.0' 3/10/77. NxCs at 476.0'. N wireline rods at 590.0'. Bx wireline core 627.0 to 657.0'. Pulled rods to check bit. | 80 | | | | | | | | 80 | | | 681.6-683.0 MUDSTONE: Dark gray to black; massive. |
| | | | | | | | | | | | | 683.0-686.6 MUDSTONE: Gray; interbedded with some sandstone and coaly material. |
| 3/11/77 - Repairs to bit. Returned to Billings. | | | | | | | | | | | | 686.6-693.2 COAL: Badly broken. |
| 3/14/77 - Returned to Broadus. Set tools in hole. | 90 | | | | | | | | 90 | | | 693.2-693.6 SHALE: Black; highly carbonaceous. |

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: O = Diamond, H = Hoosteliite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 10 OF 11 HOLE NO 76-108

7-1337 (10-69)
Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 11 OF 11

FEATURE White Tail Butte Study Site Little Powder River Coal Field
PROJECT EMRIA No. 13
STATE Wyoming
HOLE NO 76-108
LOCATION 2200' W. & 1200' N. of SE Corner, Sec. 24, T. 56 N., R. 73 W.
Altimeter
GROUND ELEV 4188±
DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/5/76 FINISHED 4/6/77
DEPTH OF OVERBURDEN --
TOTAL DEPTH 785.5
BEARING --
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED
LOGGED BY Hobbs (USGS) below 482.0'
LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hole at 657.0' 3/15/77. NxCs at 476.0'. N wireline rods at 590.0'. Bx wireline core 657.0 to 691.0'. Total water loss at 667.0'. Lost most of core 673.0 to 681.0 & 687.5 to 691.0'. | | | | | | | | | | | | 693.6-694.9 MUDSTONE: Dark gray; carbonaceous; earthy. |
| | 10 | | | | | | | | 10 | | | 694.9-695.2 MUDSTONE: Dark gray to black. |
| | | | | | | | | | | | | 695.2-695.5 COAL: |
| | | | | | | | | | | | | 695.5-697.0 MUDSTONE: Block; carbonaceous. |
| Hole at 691.0' 3/16/77. NxCs at 476.0'. N wireline rods at 590.0'. Bx wireline core 691.0 to 720.0'. Total water loss. Used 2400 gallons of water. | 20 | | | | | | | | 20 | | | 697.0-729.8 CLAYSTONE: Light gray; competent in parts with interbedded sandstone 701.0 to 703.0'. Carbonaceous branch at 703.5'; becomes more massive 713.0 to 729.8'. |
| | 30 | | | | | | | | 30 | | | 729.8-730.2 SANDSTONE: White to gray; very fine grained; very hard; interbedded pyrite nodules throughout; thick at top. |
| Hole at 720.0' 3/17/77. NxCs at 476.0'; N wireline rods at 590.0'. Bx wireline core 720.0 to 785.5'. Most core loss was due to uncemented sandstone washing away. | 40 | | | | | | | | 40 | | | 730.2-731.5 MUDSTONE: Gray to medium gray. |
| | | | | | | | | | | | | 731.5-738.3 SANDSTONE: No core (driller). |
| | | | | | | | | | | | | 738.3-740.0 SILTY SHALE: No core (driller). |
| | 50 | | | | | | | | 50 | | | 740.0-760.0 SANDSTONE: Pyrite nodules; no core (driller). |
| 3/18/77 - Tried washing to bottom of hole. Total water loss. Returned to Billings. | | | | | | | | | | | | 760.0-765.0 MUDSTONE: Dark gray to black; earthy; flakey with pyrite nodules up to 0.08' in diameter. |
| | 60 | | | | | | | | 60 | | | 765.0-766.6 MUDSTONE: Black. |
| 3/21/77 - Repairs on equipment. | | | | | | | | | | | | 766.6-766.9 MUDSTONE: Black with coal; impure and bony. |
| 3/22/77 - Pulled N & B wireline rods. USGS logged hole. | 70 | | | | | | | | 70 | | | 766.9-781.5 COAL: Badly broken; bright; hard; apparent cleat fractures; poor core recovery. |
| 3/23/77 - Drove on NxCs with 500-pound hammer. Broke cable, block & rope. NxCs moved 1.5'. | 80 | | | | | | | | 80 | | | 781.5-785.5 SHALE: No core (driller). |
| 3/24/77 - Filled drill holes with granulated bentonite & slurry. Shot NxCs at 400.0'. | 90 | | | | | | | | 90 | | | |
| 3/25/77 - Stuck 4x4 & water truck in snow. Returned to Billings. | | | | | | | | | | | | |

NOTES (Continued)
4/4/77 - Returned rig. Road drifted in with snow. Hammered on NxCs with 500-pound hammer.
4/5/77 - Shot NxCs at 300'. Unable to drive out NxCs. Shot NxCs at 250'. Unable to drive out NxCs. Shot NxCs at 200'. Pulled 200' of NxCs. 280' of NxCs left in hole (196-476).
4/6/77 - Plowed out road to rig & moved equipment.
4/7/77 - Returned to Billings.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: O = Diamond, H = Hoosteliite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE White Tail Butte Study Site Little Powder River Coal Field PROJECT EMRIA No. 13 STATE Wyoming SHEET 11 OF 11 HOLE NO 76-108

Depth on logs in feet
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COALFIELD, WYOMING

## GEOLOGIC LOG OF DH 76-108

GEOLOGY G. J. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1977 SHEET 3 OF 3 1305-600-133

Series
03
Slope — D 3 N — Texturol group
Erosion closs

Series Number 8006 through B037

| SLOPE CLASS | EROSION CLASS |
|---|---|
| A - 0- 3 Percent | 1 ----- Stoble |
| B - 3- 7 Percent | 2 ----- Slight |
| C - 7-12 Percent | 3 --- Moderate |
| D-12-20 Percent | 4 ---- Severe |
| E-20-35 Percent | 5 ---- Critical |
| F-35-75 Percent | |

TEXTURAL GROUP

| | | | |
|---|---|---|---|
| V | Sand, Loamy Sond | Coarse | Sandy |
| I | Sondy Loom, Fine Sandy Loom | Moderately Coarse | Loomy |
| M | Very Fine Sandy Loam, Loom, Silt Loam | Medium | Loomy |
| N | Sandy Clay Loam, Cloy Loom, Silty Cloy Loom | Moderately Fine | Loomy |
| H | Sondy Cloy, Silty Cloy, Lt., M & H Cloy | Fine | Cloyey |

## CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Cloy spot
- Gravelly spot
- Gumbo, slick or scoby spot (sodic)
- Dumps and similar nonsoil oreos
- Rock outcrop (includes shole ond sondstone)
- Baked rock - clinker (locol nome scorio)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greosewood

WATER FEATURES

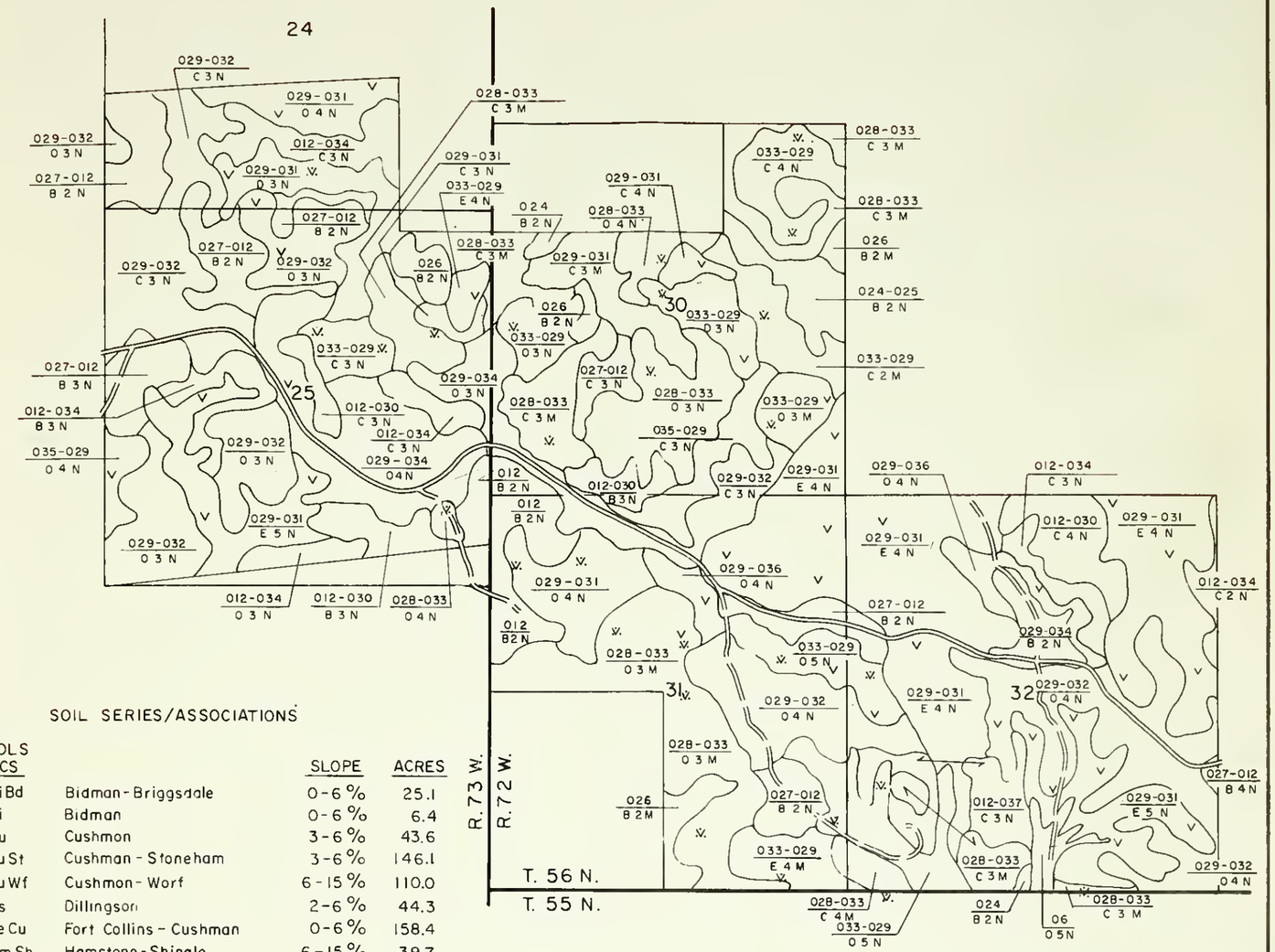
- Morsh or swamp
- Spring
- Well, ortesion
- Well, irrigotion
- Wet spot

PITS

- Grovel
- Mine

DAMS

- Medium or smoll




Section 30, 31, 32, T. 56 N - 72 W.
Section 24, 25, T. 56 N. - R. 73 W.
1 : 24 000

SOIL SERIES/ASSOCIATIONS

| MAP SYMBOLS BR/BLM | SCS | | SLOPE | ACRES |
|---|---|---|---|---|
| C24-025 | BiBd | Bidman - Briggsdale | 0-6 % | 25.1 |
| 024 | Bi | Bidman | 0-6 % | 6.4 |
| 012 | Cu | Cushmon | 3-6 % | 43.6 |
| 012-030 | CuSt | Cushman - Stoneham | 3-6 % | 146.1 |
| 012-034 | CuWf | Cushmon - Worf | 6-15 % | 110.0 |
| 026 | Ds | Dillingson | 2-6 % | 44.3 |
| 027-012 | FeCu | Fort Collins - Cushman | 0-6 % | 158.4 |
| 035-029 | HmSh | Hamstone - Shingle | 6-15 % | 39.7 |
| 028-033 | SeWx | Sear - Wibaux | 6-15 % | 368.6 |
| 029-036 | ShRo | Shingle - Rock outcrop | 10-30% | 35.1 |
| 029-031 | ShSl(gl) | Shingle - Samsil (gullied) | 15-60% | 590.0 |
| 029-032 | ShTd(rl) | Shingle - Thedlund (rolling) | 10-30% | 449.7 |
| 029-034 | ShWf | Shingle - Worf | 0-10% | 148.4 |
| 006 | Te | Terrace Escorpment | 8-35% | 12.7 |
| 033-029 | Wx(ro)Sh | Wibaux (rock outcrop) Shingle | 6-45% | 277.9 |

NOTE

Wyoming State Number 8006 - 8036

Map Number 006 - 036

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING

**SOILS MAP**

LANDS H.B. WARD — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MAY, 1977 — 1305-600-145

# APPENDIX D

## OVERBURDEN - SOIL AND BEDROCK

Series

Slope — 03 / D 3 N — Textural group

Erosion class

Series Number B006 through B037

| SLOPE CLASS | EROSION CLASS |
|---|---|
| A - 0- 3 Percent | 1 ----- Stoble |
| B - 3- 7 Percent | 2 ---- Slight |
| C - 7-12 Percent | 3 --- Moderate |
| D-12-20 Percent | 4 ---- Severe |
| E-20-35 Percent | 5 ---- Critical |
| F-35-75 Percent | |

TEXTURAL GROUP

- V { Sand, Loamy Sand } Coarse } Sandy
- I { Sandy Loam, Fine Sandy Loam } Moderotely Coarse
- M { Very Fine Sandy Loam, Loam, Silt Loam } Medium
- N { Sandy Clay Loam, Clay Loam, Silty Cloy Loam } Moderately Fine
- } Loamy
- H { Sandy Cloy, Silty Clay, Lt., M & H Clay } Fine } Clayey

## CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shole and sondstone)
- Baked rock - clinker (local name scorio)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small

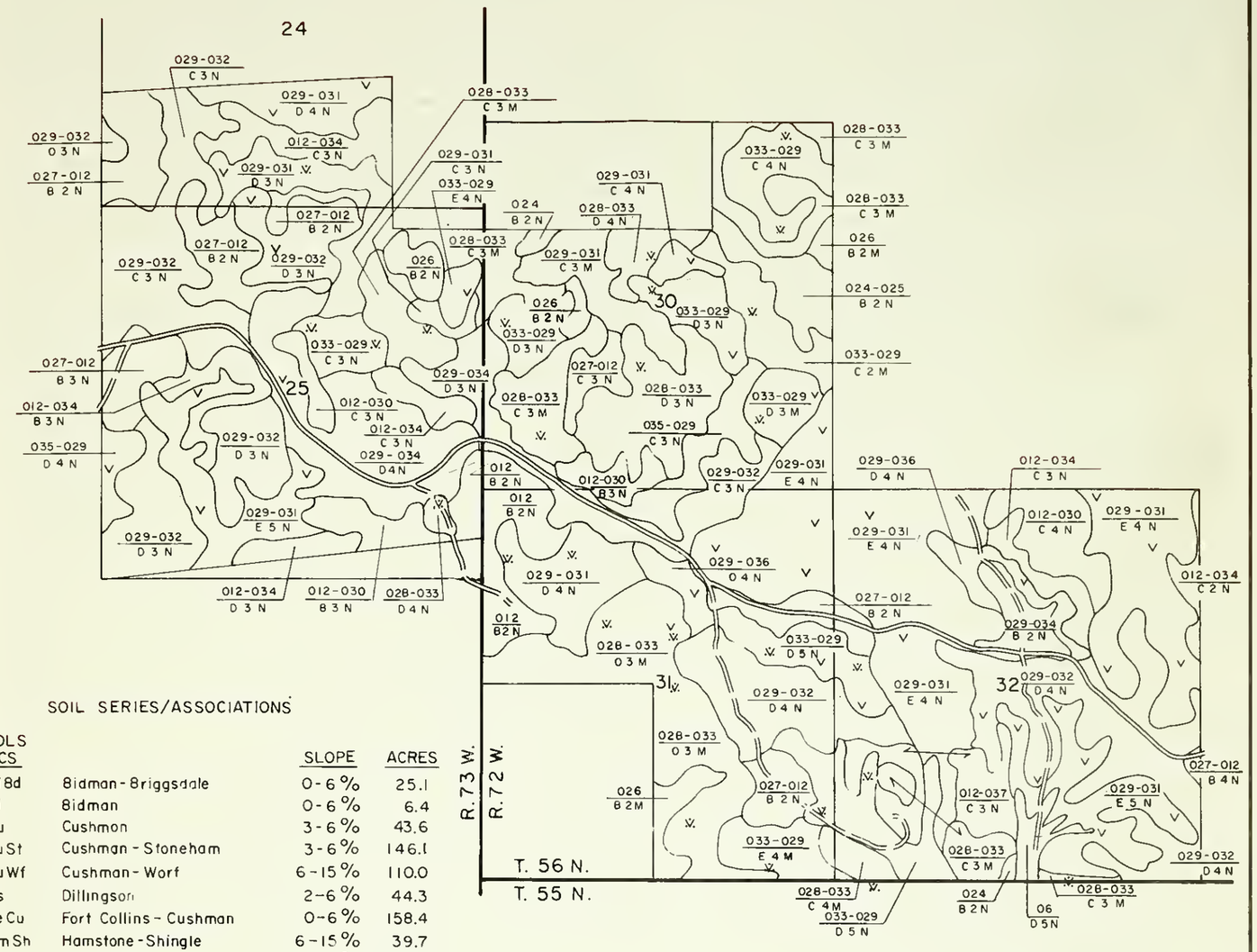
SOIL SERIES/ASSOCIATIONS

| MAP SYMBOLS BR/BLM | SCS | | SLOPE | ACRES |
|---|---|---|---|---|
| C24-025 | Bi Bd | Bidman - Briggsdale | 0-6 % | 25.1 |
| 024 | Bi | Bidman | 0-6 % | 6.4 |
| 012 | Cu | Cushmon | 3-6 % | 43.6 |
| 012-030 | Cu St | Cushman - Stoneham | 3-6 % | 146.1 |
| 012-034 | Cu Wf | Cushman - Worf | 6-15 % | 110.0 |
| 026 | Ds | Dillingson | 2-6 % | 44.3 |
| 027-012 | Fe Cu | Fort Collins - Cushman | 0-6 % | 158.4 |
| 035-029 | Hm Sh | Hamstone - Shingle | 6-15 % | 39.7 |
| 028-033 | Se Wx | Sear - Wibaux | 6-15 % | 368.6 |
| 029-036 | Sh Ro | Shingle - Rock outcrop | 10-30 % | 35.1 |
| 029-031 | Sh Sl(gl) | Shingle - Samsil (gullied) | 15-60 % | 590.0 |
| 029-032 | Sh Td(rl) | Shingle - Thedlund (rolling) | 10-30 % | 449.7 |
| 029-034 | Sh Wf | Shingle - Worf | 0-10 % | 148.4 |
| 006 | Te | Terrace Escarpment. | 8-35 % | 12.7 |
| 033-029 | Wx(ro)Sh | Wiboux(rock outcrop) Shingle | 6-45 % | 277.9 |

NOTE

Wyoming State Number 8006 - 8036

Map Number 006 - 036




Section 30, 31, 32, T. 56 N - 72 W.
Section 24, 25, T. 56 N. - R. 73 W.
1 : 24 000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

WHITE TAIL BUTTE STUDY AREA
LITTLE POWDER RIVER COAL FIELD-WYOMING

**SOILS MAP**

LANDS H.B. WARD — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MAY, 1977 — 1305-600-145

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: White Tail Butte
Location. Sec. 3C Twp. 56N Range R72W
240 E., 120' N., S¼ cor.; Profile #25
Climate: Continental - semiarid
Land Use: Range

Relief: Normal
Elevation: 4210'
Slope: Aspect: N
Vegetation: Mid and short grasses with big sage
Erosion: Slight-sheet

Stoniness: None
Drainage: Well drained (surface)
Ground Water: None
Land Form: Residual uplands

Parent Material: Fort Union
Soil Series: Hamstone
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | PROFILE DESCRIPTION |
|---|---|---|
| | 0 - .03 | A2 A light brownish gray 2.5Y 6/2 silt loam, grayish brown 2.5Y 5/2 when moist; fine angular blocky structure parting to medium crumb; soft when dry, loose when moist; nonsticky and nonplastic when wet; noncalcareous; many roots; abrupt boundary. |
| | .03 - .05 | AB A pale brown 10YR 6/3 silt loam, grayish brown 10YR 5/2 when moist; medium blocky strucutre parting to fine blocky structure; slightly hard when dry, friable when moist; nonsticky and nonplastic when wet; noncalcareous; many roots; gradual boundary. |
| 6924 T919 | .05 - .18 | B2t A pale brown 10YR 6/3 clay loam, brown 10YR 4/3 when moist; medium prismatic parting to moderate blocky; slightly hard when dry, friable when moist; sticky and plastic when wet; noncalcareous; many roots; gradual boundary. |
| | .18 - .25 | B3ca A very pale brown 10YR 7/3 clay loam, brown 10YR 5/3 when moist; medium prismatic parting to medium blocky; hard when dry, friable when moist; slightly sticky and slightly plastic when wet; calcareous; many roots; abrupt boundary. |
| 6925 T920 | .25 - .46 | C1ca A pale brown 10YR 6/3 clay loam, brown 10YR 5/3 when moist; coarse blocky structure parting to medium blocky; hard when dry, friable when moist; slightly sticky and plastic when wet; calcareous; few roots; gradual boundary. |
| 6926 T921 | .46 - .76 | C2ca A very pale brown 10YR 7/3 silty clay loam with white 10YR 8/1 mottling, pale brown 10YR 6/3 with white 8/2 mottling when moist; coarse blocky structure parting to medium blocky; very hard when dry, firm when moist; sticky and plastic when wet; calcareous; few roots; abrupt boundary. |
| 6927 T922 | .76 - 1.4 | C3ca A light grayish brown 2.5Y 6/2 silty clay loam with yellow 10YR 7/6 mottling, grayish brown 2.5Y 5/2 with white 10YR 8/2 mottling when moist; massive; very hard when dry, firm when moist; sticky and plastic when wet; calcareous; no roots; abrupt boundary. |
| 6928 T923 | 1.4 - 2.0 | C4ca A light grayish brown 2.5Y 6/2 silty clay loam with very pale brown 10YR 7/4, light brownish gray 2.5Y 6/2 with pale brown 10YR 7/3 when moist; massive; very hard when dry, firm when moist; sticky and plastic when wet; no roots; calcareous; abrupt boundary. |
| | | R The silty shale was not penetrable below 2 meters with a hand auger. |

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 6924 | 6925 | 6926 | 6927 | 6928 |
| DEPTH | (cm) | 0-.18 | .18-.46 | .46-.76 | .76-1.4 | 1.4-2.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| Total Sand | (2.0-0.05 mm) | 27.2 | 24.9 | 7.8 | 0.9 | 1.6 |
| Silt | (0.05-0.002 mm) | 40.7 | 42.7 | 57.6 | 64.6 | 65.7 |
| Clay | (< 0.002 mm) | 32.1 | 32.4 | 34.6 | 34.5 | 32.7 |
| TEXTURAL CLASS (LAB) | | Cl | Cl | SiCl | SiCl | SiCl |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | |
| 6th hr | | 5.6 | 2.7 | 1.4 | 0.64 | 0.81 |
| 24th hr | | 5.5 | 2.4 | 1.2 | 0.61 | 0.81 |
| SETTLING VOLUME | (ml) | 28 | 27 | 27 | 29 | 29 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | 33.2 | 33.4 | 36.9 | 38.4 | 38.3 |
| 1/3 bar | | 26.6 | 26.3 | 28.8 | 32.0 | 31.8 |
| 15 bar | | 18.1 | 14.8 | 14.1 | 15.5 | 17.9 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 6.9 | 7.9 | 8.2 | 8.6 | 8.1 |
| 1:2 0.01 M $CaCl_2$ | | 6.7 | 7.4 | 7.5 | 8.0 | 7.8 |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.2 | -0.4 | -0.3 | +0.8 | -4.4 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 62.5 | 36.1 | 61.4 | 75.3 | 78.0 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.74 | 0.65 | 0.68 | 1.4 | 6.0 |
| $Ca^{++}$ | (me/l) | 6.19 | 4.34 | 1.70 | 0.93 | 18.51 |
| $Mg^{++}$ | (me/l) | 2.71 | 2.53 | 2.17 | 4.43 | 47.78 |
| $Na^{+}$ | (me/l) | 0.57 | 0.53 | 1.58 | 8.87 | 31.39 |
| $K^{+}$ | (me/l) | 0.31 | 0.14 | 0.12 | 0.22 | 0.93 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 5.56 | 3.60 | 3.32 | 3.60 | 3.20 |
| $Cl^{-}$ | (me/l) | 0.08 | 0.00 | 0.24 | 1.28 | 1.96 |
| $SO_4^{-}$ | (me/l) | 1.87 | 2.06 | 0.85 | 9.60 | 93.9 |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.02 | 0.14 | 0.06 | 0.06 |
| SAR | (me/l) | 0.3 | 0.3 | 1.1 | 5.4 | 5.5 |
| Na | (me/100g) | 0.04 | 0.01 | 0.10 | 0.67 | 2.45 |
| Ca+Mg | (me/100g) | 0.56 | 0.25 | 0.26 | 0.40 | 5.17 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.20 | 0.26 | 0.14 | 0.36 | 0.16 |
| Ca+Mg | (me/l) | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 0.2 | 0.4 | 0.8 | 4.4 | 3.2 |
| ACIDITY | | | | | | |
| 1N KCl exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 23.8 | 20.8 | 19.4 | 20.3 | 18.3 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 10

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Reclamation Area: White Tail Butte
Location. Sec. 25 Twp. 56N Range 73W
930' N., 130' W., SE cor.; Profile #29
Climate: Continental - semiarid
Land Use: Range

Relief: Normal
Elevation: 4125'
Slope: Aspect: West
Vegetation: Mid and short grasses and forbes
Erosion: Moderate - rill

Stoniness: None
Drainage: Well drained surface
Ground Water: None
Land Form: Undulating upland

Parent Material: Fort Union Sandy Shales
Soil Series: Cushman
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | PROFILE DESCRIPTION | |
|---|---|---|---|
| 6948 T943 | 0 - .03 | (A1 | A light brownish gray 10YR 6/2 silt loam, dark grayish brown when moist; medium platy structure parting to medium crumb; soft when dry, loose when moist; nonsticky and nonplastic when wet; noncalcareous; many fine roots: abrupt boundary. |
| | .03 - .05 | (AB | A light brownish gray 10YR 6/2 silt loam, dark grayish brown when moist; medium blocky structure parting to fine blocky; soft when dry, loose when moist; slightly sticky and plastic when wet; noncalcareous; many fine roots; gradual boundary. |
| | .05 - .15 | (B21t | A brown 10YR 5/3 clay, dark brown 10YR 3/3 when moist; medium prismatic parting to fine blocky structure; moderately thick continuous clay skins on ped faces; hard when dry, friable when moist; very sticky and very plastic when wet; noncalcareous; many fine roots; gradual boundary. |
| | .15 - .25 | (B22t | A brown 10YR 5/3 clay, brown 10YR 4/3 when moist; coarse prismatic structure parting to medium blocky with moderately thick continuous clay skins on ped faces; hard when dry, friable when moist; very sticky and very plastic when wet; many fine roots; noncalcareous; gradual boundary. |
| 6949 T944 | .25 - .45 | (B3ca | A pale brown 10YR 6/3 silty clay loam, brown 10YR 5/3 when moist; coarse prismatic structure parting to medium blocky; hard when dry, friable when moist; sticky and plastic when wet; calcareous; many fine roots; abrupt boundary. |
| | .45 - .76 | (C1ca | A very pale brown 10YR 7/3 silty clay loam, pale brown 10YR 6/3 when moist; coarse blocky structure parting to medium blocky; very hard when dry, friable when moist; sticky and plastic when wet; few fine roots; calcareous; abrupt boundary. |
| 6950 T945 | .76 - 1.1 | C2ca | A very pale brown 10YR 7/4 silty clay with yellow 10YR 7/6 mottling, yellowish brown 10YR 5/4 with brownish yellow 10YR 6/6 mottling when moist; massive; slightly hard when wet, friable when moist; sticky and plastic when wet; calcareous; no roots; abrupt boundary. |
| 6951 T946 | 1.1 - 1.5 | C3ca | A very pale brown 10YR 7/3 clay loam, pale brown 10YR 6/3 when moist; massive; slightly hard when dry, friable when moist; slightly sticky and slightly plastic when wet; calcareous; no roots; abrupt boundary. |
| 6952 T947 | 1.5 - 2.0 | C4ca | A light gray 10YR 7/2 silt loam, light brownish gray 10YR 6/2 when moist; massive; hard when dry, firm when moist; nonsticky and nonplastic when wet; calcareous; no roots; abrupt boundary. |
| 6953 T948 | 2.0 - 2.4 | IIC5ca | A very pale brown silty clay loam, pale brown 10YR 6/3 when moist, massive; extremely hard when dry; extremely firm when moist; slightly sticky and slightly plastic when wet; calcareous; abrupt boundary. |
| 6954 T949 | 2.4 - 3.0 | IIC6ca | A light gray 10YR 7/2 loam, gray 10YR 6/1 when moist; massive; hard when dry, friable when moist; nonsticky and nonplastic when wet; calcareous. |

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 6948 | 6949 | 6950 | 6951 | 6952 | 6953 | 6954 |
| DEPTH | (cm) | 0-.25 | .25-.76 | .76-1.1 | 1.1-1.5 | 1.5-2.0 | 2.0-2.4 | 2.4-3.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | | | | | | | |
| Coarse Sand | (1.0-0.5mm) | | | | | | | |
| Medium Sand | (0.5-0.25mm) | | | | | | | |
| Fine Sand | (0.25-0.10mm) | | | | | | | |
| Very Fine Sand | (0.10-0.05mm) | | | | | | | |
| Total Sand | (2.0-0.05mm) | 18.3 | 6.1 | 5.6 | 23.5 | 22.5 | 13.4 | 36.0 |
| Silt | (0.05-0.002mm) | 38.1 | 53.9 | 48.4 | 46.9 | 54.3 | 57.1 | 44.4 |
| Clay | (<0.002mm) | 43.6 | 40.0 | 46.0 | 29.6 | 23.2 | 29.5 | 19.6 |
| TEXTURAL CLASS (LAB.) | | C | SiCl | SiC | Cl | SiL | SiCl | L |
| BULK DENSITY | ($g/cm^3$) | | | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | | | |
| 6th hr | | 2.1 | 1.8 | 1.1 | 1.2 | 1.5 | 1.3 | 1.8 |
| 24th hr | | 1.9 | 1.7 | 1.2 | 1.2 | 1.6 | 1.5 | 1.8 |
| SETTLING VOLUME | (ml) | 28 | 26 | 27 | 25 | 26 | 28 | 25 |
| MOISTURE RETENTION | (percent) | | | | | | | |
| 1/10 bar | | 34.3 | 37.0 | 40.9 | 38.1 | 39.9 | 41.0 | 37.6 |
| 1/3 bar | | 26.9 | 28.7 | 33.4 | 27.0 | 27.3 | 32.4 | 24.5 |
| 15 bar | | 17.2 | 15.4 | 19.8 | 13.4 | 12.9 | 15.4 | 10.2 |
| SOIL REACTION-pH | | | | | | | | |
| Paste | | | | | | | | |
| 1:5 $H_2O$ | | 7.5 | 7.9 | 8.0 | 8.3 | 8.4 | 8.4 | 8.1 |
| 1:2 0.01 M $CaCl_2$ | | 7.1 | 7.7 | 8.0 | 8.0 | 8.0 | 8.0 | 7.9 |
| ORGANIC CARBON | (percent) | | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.2 | -3.7 | -12. | -4.6 | -9.4 | -13. | -6.9 |
| SATURATION EXTRACT | | | | | | | | |
| Saturation Percentage | | 58.7 | 66.6 | 76.0 | 67.5 | 70.0 | 76.8 | 67.3 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.86 | 4.0 | 9.0 | 9.0 | 9.5 | 11.0 | 8.5 |
| $Ca^{++}$ | (me/l) | 4.06 | 24.15 | 22.60 | 13.57 | 22.46 | 23.05 | 23.15 |
| $Mg^{++}$ | (me/l) | 3.98 | 32.15 | 98.52 | 77.63 | 87.58 | 99.51 | 69.65 |
| $Na^{+}$ | (me/l) | 0.81 | 10.91 | 47.61 | 43.57 | 44.74 | 48.91 | 36.61 |
| $K^{+}$ | (me/l) | 0.15 | 0.30 | 0.72 | 0.81 | 1.01 | 1.14 | 0.97 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 6.84 | 2.52 | 6.48 | 1.80 | 1.40 | 1.32 | 1.28 |
| $Cl^{-}$ | (me/l) | 0.52 | 0.52 | 3.32 | 2.80 | 2.96 | 4.20 | 3.00 |
| $SO_4^{-}$ | (me/l) | 1.60 | 62.46 | 171.77 | 135.75 | 161.98 | 170.73 | 127.00 |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.05 | 0.06 | 0.04 | 0.06 | 0.06 | 0.44 |
| SAR | (~~me/l~~) | 0.40 | 2.1 | 6.1 | 6.5 | 6.0 | 6.2 | 5.4 |
| Na | (me/100g) | 0.05 | 0.73 | 3.62 | 2.94 | 3.13 | 3.76 | 2.46 |
| Ca+Mg | (me/100g) | 0.47 | 3.75 | 9.20 | 6.16 | 7.70 | 9.41 | 6.25 |
| 1:5 EXTRACT | | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.32 | 1.4 | 2.9 | 1.7 | 3.4 | 4.0 | 2.0 |
| Ca+Mg | (me/l) | | | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 0.2 | 0.3 | 5.2 | 2.9 | 2.6 | 2.2 | 2.0 |
| ACIDITY | | | | | | | | |
| IN KCl exchange acidity | | | | | | | | |
| Total | (me/100g) | | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 21.9 | 17.5 | 19.0 | 15.7 | 16.9 | 18.4 | 15.9 |
| NaOAc@pH 8.2 | | | | | | | | |
| BORON | (mg/l) | | | | | | | |

Table II

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Reclamation Area: White Tail Butte
Location. Sec. 30 Twp. 56N Range 72W
1120' S., 520' W., of NE cor.; Profile #26
Climate: Continental - semiarid
Land Use: Range

Relief: Normal
Elevation: 4030'
Slope: Aspect: N
Vegetation: Mid and short grasses with few forbes
Erosion: Moderate

Staniness:
Drainage: Well drained (surface)
Ground Water: None
Land Form: Undulating uplands

Parent Material: Baked rock
Soil Series: Webaux
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | | PROFILE DESCRIPTION |
|---|---|---|---|
| | 0 - .05 | (A1 | A reddish brown 5YR 5/3 silt loam, dark reddish gray 5YR 4/2 when moist; coarse crumb structure parting to medium crumb; soft dry, loose moist; nonsticky and nonplastic when wet; many fine roots; 15 percent baked rock fragments; noncalcareous; abrupt boundary. |
| | .05 - .12 | (AB | A reddish brown 5YR 4/3 silt loam, dark reddish brown 5YR 3/3 when moist; medium blocky structure parting to fine blocky; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; noncalcareous; many fine roots; 15 percent baked rock fragments; gradual boundary. |
| 6942 T937 | .12 - .25 | (B21 | A reddish brown 5YR 5/3 silt loam, reddish brown 5YR 4/3 when moist; medium prismatic structure parting to fine blocky; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; many fine roots; noncalcareous; 15 percent baked rock fragments; gradual boundary. |
| | .25 - .60 | (B22 | A reddish brown 5YR 5/3 silt loam, reddish brown 5YR 4/3 when moist; coarse prismatic structure parting to moderate blocky; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; noncalcareous; many fine roots; 15 percent baked rock fragments; gradual boundary. |
| 6943 T938 | .60 - .90 | B3ca | A light reddish brown 5YR 6/3 silt loam, reddish brown 5YR 5/3 when moist; coarse blocky structure parting to medium blocky; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; moderately calcareous; many fine roots; less than 5 percent baked rock fragments; abrupt boundary. |
| 6944 T939 | .90 - 1.4 | C1ca | A pinkish gray 5YR 6/2 silt loam, reddish brown 5YR 5/3 when moist; coarse to very coarse blocky structure parting to medium blocky; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; occasional fine root; less than 5 percent baked rock fragments; abrupt boundary. |
| 6945 T940 | 1.4 - 1.8 | IIC2ca | A pinkish gray 7.5YR 7/2 silt loam, reddish brown 5YR 5/3 when moist; massive; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; noncalcareous; no roots; 25 percent baked rock fragments; abrupt boundary. |
| 6946 T941 | 1.8 - 2.4 | IIC3ca | A pinkish gray 7.5YR 7/2 silt loam, dark brown when moist; massive; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; noncalcareous; no roots; 25 percent baked rock fragments; gradual boundary. |
| 6947 T942 | 2.4 - 3.0 | IIIC4ca | A pale brown 10YR 6/3 silt loam, brown 10YR 5/3 when moist; massive consolidated sandy shale; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; noncalcareous; no roots. |

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | |
|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 6942 | 6943 | 6944 | 6945 | 6946 | 6947 |
| DEPTH | (cm) | 0-.60 | .60-.90 | .90-1.4 | 1.4-1.8 | 1.8-2.4 | 2.4-3.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | | | | | | |
| Coarse Sand | (1.0-0.5mm) | | | | | | |
| Medium Sand | (0.5-0.25mm) | | | | | | |
| Fine Sand | (0.25-0.10mm) | | | | | | |
| Very Fine Sand | (0.10-0.05mm) | | | | | | |
| Total Sand | (2.0-0.05mm) | 28.8 | 28.7 | 27.8 | 28.7 | 23.7 | 27.0 |
| Silt | (0.05-0.002mm) | 54.4 | 52.0 | 51.8 | 54.1 | 53.8 | 51.3 |
| Clay | (<0.002mm) | 16.8 | 19.3 | 20.4 | 17.2 | 22.5 | 21.7 |
| TEXTURAL CLASS (LAB) | | SiL | SiL | SiL | SiL | SiL | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | | |
| 6th hr | | 3.0 | 1.0 | 0.78 | 0.71 | 1.2 | 1.4 |
| 24th hr | | 2.8 | 0.99 | 0.81 | 0.74 | 1.2 | 1.4 |
| SETTLING VOLUME | (ml) | 26 | 24 | 23 | 22 | 23 | 21 |
| MOISTURE RETENTION | (percent) | | | | | | |
| 1/10 bar | | 46.5 | 45.8 | 41.8 | 41.8 | 38.3 | 36.3 |
| 1/3 bar | | 31.1 | 32.1 | 31.4 | 31.4 | 27.6 | 25.3 |
| 15 bar | | 18.3 | 16.6 | 16.7 | 15.9 | 13.8 | 12.2 |
| SOIL REACTION-pH | | | | | | | |
| Paste | | | | | | | |
| 1:5 $H_2O$ | | 7.5 | 7.9 | 8.2 | 8.3 | 8.2 | 8.2 |
| 1:2 0.01 M $CaCl_2$ | | 7.4 | 7.8 | 8.1 | 8.1 | 8.0 | 8.0 |
| ORGANIC CARBON | (percent) | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.1 | -3.8 | -11. | -6.5 | -4.2 | -7.6 |
| SATURATION EXTRACT | | | | | | | |
| Saturation Percentage | | 54.6 | 52.9 | 50.6 | 50.8 | 52.1 | 50.4 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.68 | 6.5 | 15.0 | 15.0 | 11.0 | 10.0 |
| $Ca^{++}$ | (me/l) | 4.17 | 25.60 | 24.90 | 22.36 | 22.65 | 23.15 |
| $Mg^{++}$ | (me/l) | 1.63 | 49.75 | 156.25 | 135.36 | 107.48 | 81.58 |
| $Na^{+}$ | (me/l) | 0.38 | 22.74 | 88.39 | 87.87 | 76.83 | 59.96 |
| $K^{+}$ | (me/l) | 0.70 | 2.66 | 3.96 | 3.66 | 3.02 | 2.71 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 3.84 | 3.48 | 2.04 | 2.16 | 1.92 | 1.76 |
| $Cl^{-}$ | (me/l) | 0.00 | 1.04 | 15.68 | 12.92 | 7.96 | 4.88 |
| $SO_4^{-}$ | (me/l) | 1.58 | 93.69 | 283.16 | 261.29 | 230.06 | 162.40 |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.11 | 0.19 | 0.19 | 0.22 | 0.19 |
| SAR | (me/l) | 0.2 | 3.7 | 9.3 | 9.9 | 9.5 | 8.3 |
| Na | (me/100g) | 0.02 | 1.20 | 4.47 | 4.46 | 4.00 | 3.02 |
| Ca+Mg | (me/100g) | 0.32 | 3.98 | 9.17 | 8.02 | 6.78 | 5.28 |
| 1:5 EXTRACT | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.20 | 1.7 | 3.3 | 2.5 | 2.8 | 2.4 |
| Ca+Mg | (me/l) | | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 0.3 | 3.2 | 6.9 | 9.1 | 6.5 | 5.4 |
| ACIDITY | | | | | | | |
| 1N KCl exchange acidity | | | | | | | |
| Total | (me/100g) | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 20.2 | 19.5 | 18.3 | 17.9 | 17.5 | 15.1 |
| NaOAc@pH 8.2 | | | | | | | |
| BORON | (mg/l) | | | | | | |

Table 12

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Reclamation Area: White Tail Butte
Relief: Normal
Stoniness: None
Parent Material: Fort Union Sandstone
Location. Sec. 31 Twp. 56N Range 72W
Elevation: 4235'
Soil Series: Worf
1950' E., 100' S., NW cor.; Profile #14
Slope: Aspect: N
Drainage: Well drained (surface)
Soil Classification:
Climate: Continental - semiarid
Vegetation: Mid and short grasses with big sage
Ground Water: None
Land Use: Range
Erosion: Slight-sheet
Land Form: Residual uplands
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | PROFILE DESCRIPTION |
|---|---|---|
| 6929 T924 | 0 - .03 | (A1 A light grayish brown 10YR 6/3 silt loam, dark grayish brown 10YR 4/2 when moist; coarse platy parting to medium crumb; soft when dry, friable when moist; nonsticky and nonplastic when wet; noncalcareous; few fine roots; abrupt boundary. |
| | .03 - .08 | (AB A light grayish brown 10YR 6/3 clay loam, brown 10YR 5/3 when moist; medium blocky parting to fine blocky; slightly hard when dry, friable when moist; slightly sticky and slightly plastic when wet; few fine roots; noncalcareous; gradual boundary. |
| | .08 - .15 | (B2t A grayish brown 10YR 5/2 clay loam, cark grayish brown 10YR 4/2 when moist; medium prismatic parting to fine blocky; slightly hard when dry, friable when moist; sticky and plastic when wet; noncalcareous; few fine roots; gradual boundary. |
| 6930 T925 | .15 - .38 | (B3ca A light grayish brown 10YR 6/2 silty clay loam, dark grayish brown 10YR 4/2 when moist; hard when dry, friable when moist; sticky and plastic when wet; calcareous; few fine roots; gradual boundary. |
| | .38 - .46 | (C1ca A light gray 10YR 7/2 silty clay loam, light grayish brown 10YR 6/2 when moist; coarse prismatic parting to medium blocky; hard when dry, friable moist; sticky and plastic when wet; moderately calcareous; occasional fine root; gradual boundary. |
| 6931 T926 | .46 - .91 | C2ca A light gray 10YR 7/2 clay loam, light grayish brown 2.5Y 6/2 when moist; massive; hard dry, friable moist; slightly sticky moist, plastic wet; moderately calcareous; occasional fine root; abrupt boundary. |
| 6932 T927 | .91 - 1.4 | C3ca A light gray 10YR 7/1 loam, light grayish brown 10YR 6/2 when moist; massive; very hard dry, firm moist; slightly sticky moist, slightly plastic wet; no roots; moderately calcareous; abrupt boundary. |
| 6933 T928 | 1.4 - 1.8 | C4ca A light gray 10YR 7/2 silt loam, light grayish brown 10YR 6/2 when moist; mottling in this horizon is yellow 10YR 8/8 dry, yellowish brown 10YR 5/8 moist; massive; very hard dry, firm moist; nonsticky when moist, nonplastic when wet; moderately calcareous; no roots; gradual boundary. |
| 6934 T929 | 1.8 - 2.4 | C5 A light gray 10YR 7/1 very fine sandy loam, grayish brown 10YR 5/2 when moist; mottling in this horizon is yellow 10YR 8/8 dry, yellowish brown 10YR 5/8 dry; nonsticky when moist, nonplastic when wet; calcareous; no roots; gradual boundary. |
| 6935 T930 | 2.4 - 3.0 | C6 A light gray 10YR 7/1 silty clay loam, light gray 10YR 7/2 when moist; mottling in this horizon is yellow 10YR 8/8 dry, yellowish brown 10YR 5/8 moist; massive; very hard when dry, firm when moist; very sticky moist, very plastic wet; calcareous; no roots. |

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 6929 | 6930 | 6931 | 6932 | 6933 | 6934 | 6935 |
| DEPTH | (cm) | 0-.15 | .15-.46 | .46-.91 | .91-1.4 | 1.4-1.8 | 1.8-2.4 | 2.4-3.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | | | |
| Total Sand | (2.0-0.05 mm) | 33.0 | 19.6 | 35.6 | 48.2 | 18.2 | 52.5 | 3.6 |
| Silt | (0.05-0.002 mm) | 36.9 | 44.4 | 37.3 | 29.8 | 56.8 | 28.0 | 65.8 |
| Clay | (<0.002 mm) | 30.1 | 36.0 | 27.1 | 22.0 | 25.0 | 19.5 | 30.6 |
| TEXTURAL CLASS (LAB.) | | Cl | SiCl | Cl | L | SiL | VFSL | SiCl |
| BULK DENSITY | ($g/cm^3$) | | | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | | | |
| 6th hr | | 4.4 | 2.1 | 1.9 | 1.3 | 0.81 | 2.6 | 0.64 |
| 24th hr | | 4.6 | 2.0 | 1.7 | 1.2 | 0.76 | 2.5 | 0.61 |
| SETTLING VOLUME | (ml) | 27 | 27 | 25 | 26 | 28 | 25 | 29 |
| MOISTURE RETENTION | (percent) | | | | | | | |
| 1/10 bar | | 35.3 | 37.4 | 37.3 | 35.4 | 41.8 | 30.3 | 41.1 |
| 1/3 bar | | 25.8 | 27.4 | 26.8 | 23.1 | 29.2 | 20.5 | 33.5 |
| 15 bar | | 16.3 | 15.6 | 12.4 | 10.5 | 14.2 | 8.96 | 17.2 |
| SOIL REACTION-pH | | | | | | | | |
| Paste | | | | | | | | |
| 1:5 $H_2O$ | | 7.5 | 8.0 | 8.3 | 8.8 | 8.5 | 8.1 | 7.8 |
| 1:2 0.01 M $CaCl_2$ | | 7.3 | 7.5 | 7.5 | 7.8 | 7.8 | 7.8 | 7.7 |
| ORGANIC CARBON | (percent) | | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.8 | -0.3 | +0.2 | +0.2 | -1.1 | -2.4 | -8.5 |
| SATURATION EXTRACT | | | | | | | | |
| Saturation Percentage | | 57.0 | 62.6 | 60.0 | 59.8 | 72.1 | 55.5 | 76.1 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.76 | 0.66 | 0.56 | 5.0 | 1.3 | 5.5 | 5.6 |
| $Ca^{++}$ | (me/l) | 5.29 | 4.06 | 1.76 | 15.47 | 0.99 | 22.46 | 25.70 |
| $Mg^{++}$ | (me/l) | 2.08 | 1.81 | 3.26 | 32.40 | 2.53 | 45.81 | 46.79 |
| $Na^{+}$ | (me/l) | 0.62 | 0.33 | 1.72 | 20.83 | 6.96 | 21.52 | 20.09 |
| $K^{+}$ | (me/l) | 0.21 | 0.09 | 0.11 | 0.63 | 0.16 | 0.77 | 0.90 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 4.68 | 3.92 | 3.32 | 1.88 | 3.36 | 1.68 | 1.28 |
| $Cl^{-}$ | (me/l) | 0.12 | 0.12 | 0.64 | 5.08 | 2.00 | 6.08 | 4.92 |
| $SO_4^{-}$ | (me/l) | 2.42 | 0.99 | 2.62 | 62.5 | 4.21 | 83.3 | 84.3 |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.02 | 0.07 | 0.15 | 0.11 | 1.19 | 3.71 |
| SAR | (me/l) | 0.3 | 0.2 | 1.1 | 4.3 | 5.2 | 3.7 | 3.3 |
| Na | (me/100g) | 0.04 | 0.02 | 0.10 | 1.25 | 0.50 | 1.19 | 1.53 |
| Ca+Mg | (me/100g) | 0.42 | 0.36 | 0.31 | 2.81 | 0.25 | 3.79 | 5.52 |
| 1:5 EXTRACT | | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.12 | 0.14 | 0.24 | 0.34 | 0.92 | 1.1 | 3.0 |
| Ca+Mg | (me/l) | | | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 0.2 | 1.4 | 2.0 | 1.7 | 6.5 | 2.9 | 1.0 |
| ACIDITY | | | | | | | | |
| IN KCl exchange acidity | | | | | | | | |
| Total | (me/100g) | | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 23.1 | 23.3 | 21.1 | 19.1 | 21.6 | 15.0 | 21.1 |
| NaOAc@pH 8.2 | | | | | | | | |
| BORON | (mg/l) | | | | | | | |

Table 13

GPO 833-276

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Reclamation Area: White Tail Butte
Location. Sec. 31 Twp. 56N Range 72W
1740' W., 390' S., NE cor.; Profile #13
Climate: Continental - semiarid
Land Use: Range

Relief: Normal
Elevation: 4240'
Slope: Aspect: North
Vegetation: Mid and short grasses and sage
Erosion: Moderate - Rill

Stoniness: None
Drainage: Well drained (surface)
Ground Water: None
Land Form: Residual upland

Parent Material: Fort Union Sandstone
Soil Series: Shingle
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | PROFILE DESCRIPTION |
|---|---|---|
| 6911 T900 | 0 - .13 | (A1 A very pale brown 10YR 7/3 silty clay loam, pale brown 10YR 6/3 when moist; medium blocky strucutre parting to very fine granular; loose when dry, loose when moist; slightly calcareous; many roots; gradual boundary. |
| | .13 - .23 | (C1ca A light gray 10YR 7/2 silty clay loam, light brownish gray 10YR 6/2 when moist; coarse platy structure parting to fine angular blocky; slightly hard when dry, friable when moist; slightly stickly and slightly plastic when wet; many roots; moderately calcareous; abrupt boundary. |
| 6912 T901 | .23 - .46 | C2ca A pale brown 10YR 6/3 silt loam, brown 10YR 5/3 when moist; coarse platy structure parting to medium angular blocking; slightly hard when dry, firable when moist; nonsticky and nonplastic when wet; moderately calcareous; few roots; abrupt boundary. |
| 6913 T902 | .46 - .76 | C3ca A light gray 10YR 7/2 silty clay loam, light grayish brown 10YR 6/2 when moist; very coarse platy structure parting to coarse platy; slightly hard when dry, friable when moist; sticky and plastic when wet; moderately calcareous; very few roots; gradual boundary. |
| 6914 T903 | .76 - 1.2 | C4ca A light gray 10YR 7/2 silty clay loam, light grayish brown 10YR 6/2 when moist; consolidated silty shale; hard when dry, very firm when moist; slightly sticky and slightly plastic when wet; calcareous; no roots; gradual boundary. |
| 6915 T904 | 1.2 - 1.5 | C5ca A pale brown 10YR 6/3 silt loam, brown 10YR 5/3 when moist; consolidated silty shale; hard when dry, very firm when moist; nonsticky and nonplastic when wet; moderately calcareous; no roots; diffuse boundary. |
| 6916 T905 | 1.5 - 2.1 | C6ca A light gray 10YR 7/2 loam, light brownish gray 10YR 6/2 when moist; consolidated silty shale; very hard when dry, very firm when moist; slightly sticky and slightly plastic when wet; calcareous; no roots; abrupt boundary. |
| 6917 T906 | 2.1 - 2.6 | C7 A very pale brown 10YR 7/3 silty clay loam, pale brown 10YR 6/3 when moist; consolidated silty shale; very hard when dry, very firm when moist; sticky and plastic when wet; calcareous; abrupt boundary. |
| 6918 T907 | 2.6 - 3.0 | C8 A very pale brown 10YR 7/3 silty clay loam, pale brown when when moist; consolidated silty shale; very hard when dry, friable when moist; calcareous. |

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 6911 | 6912 | 6913 | 6914 | 6915 | 6916 | 6917 | 6918 |
| DEPTH | (cm) | 0-.23 | .23-.46 | .46-.76 | .76-1.2 | 1.2-1.5 | 1.5-2.1 | 2.1-2.6 | 2.6-3.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | | | | | | | | |
| Coarse Sand | (1.0-0.5mm) | | | | | | | | |
| Medium Sand | (0.5-0.25mm) | | | | | | | | |
| Fine Sand | (0.25-0.10mm) | | | | | | | | |
| Very Fine Sand | (0.10-0.05mm) | | | | | | | | |
| Total Sand | (2.0-0.05mm) | 15.5 | 9.4 | 6.2 | 5.8 | 14.8 | 28.4 | 1.3 | 2.5 |
| Silt | (0.05-0.002mm) | 56.5 | 65.6 | 64.0 | 66.8 | 61.5 | 45.6 | 65.4 | 66.4 |
| Clay | (<0.002mm) | 28.0 | 25.0 | 29.8 | 27.4 | 23.7 | 26.0 | 33.3 | 31.1 |
| TEXTURAL CLASS (LAB.) | | SiCl | SiL | SiCl | SiCl | SiL | L | SiCl | SiCl |
| BULK DENSITY | ($g/cm^3$) | | | | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | | | | |
| 6th hr | | 3.7 | 4.6 | 1.1 | 0.66 | 1.0 | 1.5 | 0.45 | 0.40 |
| 24th hr | | 3.6 | 4.1 | 1.1 | 0.74 | 0.99 | 1.4 | 0.45 | 0.38 |
| SETTLING VOLUME | (ml) | 28 | 29 | 27 | 29 | 28 | 27 | 30 | 30 |
| MOISTURE RETENTION | (percent) | | | | | | | | |
| 1/10 bar | | 35.4 | 35.2 | 29.1 | 42.1 | 39.4 | 38.4 | 41.4 | 40.4 |
| 1/3 bar | | 27.4 | 29.5 | 32.5 | 34.2 | 31.9 | 29.6 | 33.7 | 32.7 |
| 15 bar | | 16.6 | 17.6 | 19.4 | 20.3 | 18.0 | 16.7 | 19.8 | 17.7 |
| SOIL REACTION-pH | | | | | | | | | |
| Paste | | | | | | | | | |
| 1:5 $H_2O$ | | 8.1 | 7.6 | 7.9 | 8.0 | 8.1 | 8.2 | 8.2 | 8.2 |
| 1:2 0.01 M $CaCl_2$ | | 7.5 | 7.5 | 7.8 | 7.9 | 7.9 | 7.9 | 7.9 | 7.8 |
| ORGANIC CARBON | (percent) | | | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -1.2 | -4.5 | -17. | -18. | -15. | -15. | -4.1 | -2.4 |
| SATURATION EXTRACT | | | | | | | | | |
| Saturation Percentage | | 6.33 | 74.0 | 79.8 | 75.4 | 71.8 | 69.0 | 77.9 | 77.5 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.54 | 4.0 | 7.5 | 8.5 | 7.0 | 6.0 | 2.0 | 5.5 |
| $Ca^{++}$ | (me/l) | 5.79 | 31.69 | 23.25 | 22.31 | 22.16 | 22.31 | 20.96 | 14.42 |
| $Mg^{++}$ | (me/l) | 1.18 | 10.44 | 90.54 | 105.5 | 95.56 | 86.60 | 67.68 | 43.75 |
| $Na^{+}$ | (me/l) | 0.38 | 2.44 | 19.52 | 25.26 | 27.25 | 26.48 | 25.74 | 22.13 |
| $K^{+}$ | (me/l) | 0.23 | 0.64 | 1.29 | 1.22 | 1.08 | 1.04 | 1.52 | 1.29 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 4.84 | 2.60 | 1.36 | 1.32 | 1.24 | 1.32 | 1.64 | 1.76 |
| $Cl^{-}$ | (me/l) | 0.04 | 0.20 | 1.56 | 1.76 | 1.64 | 1.32 | 1.60 | 1.16 |
| $SO_4^{-}$ | (me/l) | 0.90 | 43.5 | 124. | 140. | 136. | 128. | 108. | 76.6 |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.37 | 1.42 | 1.68 |
| SAR | (me/l) | 0.2 | 0.5 | 2.6 | 3.2 | 3.6 | 3.6 | 3.9 | 4.1 |
| Na | (me/100g) | 0.02 | 0.18 | 1.56 | 1.90 | 1.96 | 1.83 | 2.01 | 1.72 |
| Ca+Mg | (me/100g) | 0.44 | 3.12 | 9.09 | 9.64 | 8.45 | 6.12 | 6.90 | 4.51 |
| 1:5 EXTRACT | | | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.20 | 2.6 | 3.6 | 4.0 | 3.8 | 3.6 | 2.0 | 1.2 |
| Ca+Mg | (me/l) | | | | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 0.63 | 0.37 | 0.78 | 2.9 | 2.7 | 1.8 | 2.6 | 2.9 |
| ACIDITY | | | | | | | | | |
| 1N KCl exchange acidity | | | | | | | | | |
| Total | (me/100g) | | | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 23.9 | 21.7 | 23.0 | 24.1 | 24.3 | 24.1 | 26.4 | 27.8 |
| NaOAc@pH 8.2 | | | | | | | | | |
| BORON | (mg/l) | | | | | | | | |

Table 14

GPO 833-276

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Reclamation Area: White Tail Butte
Location. Sec. 31 Twp. S6N Range 72W
2260' W., 170' S., E¼ cor.; Profile #15
Climate: Continental - semiarid
Land Use: Range

Relief: Normal
Elevation: 4160'
Slope: Aspect: S
Vegetation: Mid and short grasses and big sage
Erosion: Slight

Stoniness: 15 percent in surface foot
Drainage: Well drained (surface)
Ground Water: None
Land Form: Colluvial slopes

Parent Material: Baked rock
Soil Series: Dillingson
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | | PROFILE DESCRIPTION |
|---|---|---|---|
| | 0 - .08 | (A1 | A reddish brown 5YR S/3 silt loam, dark reddish brown 5YR 3/3 moist; coarse platy parting to medium blocky; soft dry, very friable moist; nonsticky when moist; nonplastic when wet; noncalcareous; baked rock fragments 15 percent; unable to determine root population; abrupt boundary. |
| | .08 - .18 | (AB | A reddish brown S YR 5/3 silt loam, dark reddish brown 5YR 3/3 moist; coarse blocky paring to fine and medium blocking; slightly hard dry, friable when moist; nonsticky and nonplastic when wet; noncalcareous; baked rock fragments 15 percent; unable to determine root population; gradual boundary. |
| 6936 T931 | .18 - .30 | (B21t | A reddish brown 5 YR 5/3 clay loam, reddish brown 5YR 4/3 when moist; medium prismatic parting to fine blocky; hard when dry, friable when moist; slightly sticky and slightly plastic when wet; noncalcareous; baked rock fragments 15 percent; unable to determine root population; gradual boundary. |
| | .30 - .60 | (B22t | A reddish brown 5YR 5/3 silty clay loam, reddish brown 5YR 4/3 when moist; coarse prismatic parting to medium blocky; hard when dry, friable when moist; very sticky and very plastic when wet; noncalcareous; few roots; gradual boundary. |
| 6937 T932 | .60 - 1.1 | B3ca | A reddish brown 5YR 5/3 clay loam, reddish brown 5YR 4/3 when moist; coarse prismatic parting to medium blocky; hard when dry, friable when moist; slightly sticky and slightly plastic when wet; few roots; moderately calcareous; gradual boundary. |
| 6938 T933 | 1.1 - 1.5 | C1ca | A light brown 7.5YR 6/4 silt loam, brown 7.S YR 4/4 when moist; massive; slightly hard dry, friable when moist; nonsticky and nonplastic when wet; few roots; moderately calcareous; gradual boundary. |
| 6939 T934 | 1.5 - 2.0 | C2ca | A light reddish brown 5YR 6/3 silt loam, reddish brown 5YR 4/3 when moist; massive; slightly hard dry, very friable when moist; nonsticky and nonplastic when wet; no roots; moderately calcareous; gradual boundary. |
| 6940 T935 | 2.0 - 2.6 | IIC3ca | A reddish brown 5YR 5/4 loam, reddish brown 5YR 4/4 when moist; massive; slightly hard dry, very friable when moist; nonsticky and nonplastic when wet; no roots; baked rock and clinkers 15 percent; moderately calcareous; abrupt boundary. |
| 6941 T936 | 2.6 - 3.0 | IIC4ca | A light yellowish brown 2.5Y 6/4 gravelly loam, olive brown 2.SY 4/4 when moist; massive; slightly hard dry, very friable when moist; nonsticky and nonplastic when wet; baked rock and clinkers 25 percent; moderately calcareous; no roots. |

This soil represents the uplant rocky soils developed in elevated positions from baked rock. This soil has a well developed B horizon with clay skin at 7 to 24 inches. When mixed and tested in the laboratory the clay is not detrimental. The texture of the mixed upper 24 inches is a loam. The native vegetation is blue grama, western wheat, and fescue with some forbes. Erosion is slight.

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | |
|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 6936 | 6937 | 6938 | 6939 | 6940 | 6941 |
| DEPTH | (cm) | 0-.60 | .60-1.1 | 1.1-1.5 | 1.5-2.0 | 2.0-2.6 | 2.6-3.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | | | | | | |
| Coarse Sand | (1.0-0.5mm) | | | | | | |
| Medium Sand | (0.5-0.25mm) | | | | | | |
| Fine Sand | (0.25-0.10mm) | | | | | | |
| Very Fine Sand | (0.10-0.05mm) | | | | | | |
| Total Sand | (2.0-0.05mm) | 33.4 | 20.8 | 21.6 | 28.7 | 28.6 | 39.1 |
| Silt | (0.05-0.002mm) | 41.9 | 51.6 | 56.0 | 54.0 | 48.6 | 43.7 |
| Clay | (<0.002mm) | 24.7 | 27.6 | 22.4 | 17.3 | 22.8 | 17.2 |
| TEXTURAL CLASS (LAB.) | | L | Cl | SiL | SiL | L | L |
| BULK DENSITY | ($g/cm^3$) | | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | | |
| 6th hr | | 2.7 | 1.5 | 1.1 | 1.3 | 2.0 | 3.1 |
| 24th hr | | 2.5 | 1.3 | 1.0 | 1.2 | 2.0 | 3.0 |
| SETTLING VOLUME | (ml) | 26 | 25 | 24 | 21 | 27 | 26 |
| MOISTURE RETENTION | (percent) | | | | | | |
| 1/10 bar | | 35.3 | 40.1 | 43.5 | 43.6 | 42.2 | 40.9 |
| 1/3 bar | | 25.3 | 29.9 | 32.4 | 33.0 | 30.7 | 29.3 |
| 15 bar | | 13.4 | 13.6 | 12.9 | 12.6 | 12.7 | 11.8 |
| SOIL REACTION-pH | | | | | | | |
| Paste | | | | | | | |
| 1:5 $H_2O$ | | 7.6 | 8.2 | 8.1 | 8.2 | 8.1 | 8.2 |
| 1:2 0.01 M $CaCl_2$ | | 7.1 | 7.6 | 7.7 | 7.8 | 7.9 | 7.9 |
| ORGANIC CARBON | (percent) | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.4 | 0.0 | -2.0 | -2.0 | -0.4 | -0.2 |
| SATURATION EXTRACT | | | | | | | |
| Saturation Percentage | | 50.4 | 54.7 | 57.0 | 54.1 | 54.9 | 52.6 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.84 | 0.45 | 4.5 | 5.5 | 4.5 | 4.0 |
| $Ca^{++}$ | (me/l) | 4.39 | 2.31 | 17.76 | 16.82 | 12.08 | 12.57 |
| $Mg^{++}$ | (me/l) | 2.71 | 1.90 | 33.72 | 45.81 | 32.65 | 29.85 |
| $Na^{+}$ | (me/l) | 0.81 | 0.81 | 7.26 | 16.39 | 14.91 | 11.65 |
| $K^{+}$ | (me/l) | 1.00 | 0.55 | 2.20 | 2.48 | 2.02 | 2.02 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 5.36 | 3.28 | 2.04 | 2.40 | 2.08 | 2.08 |
| $Cl^{-}$ | (me/l) | 0.36 | 0.28 | 2.12 | 3.76 | 5.92 | 5.40 |
| $SO_4^{-}$ | (me/l) | 1.79 | 1.00 | 56.8 | 77.5 | 53.1 | 50.6 |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.13 | 0.13 | 0.09 | 0.09 | 0.15 |
| SAR | (me/l) | 0.4 | 0.6 | 1.4 | 2.9 | 3.2 | 2.5 |
| Na | (me/100g) | 0.04 | 0.04 | 0.41 | 0.89 | 0.82 | 0.62 |
| Ca+Mg | (me/100g) | 0.36 | 0.23 | 2.93 | 3.39 | 2.45 | 2.23 |
| 1:5 EXTRACT | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.14 | 0.28 | 0.90 | 1.1 | 0.72 | 0.72 |
| Ca+Mg | (me/l) | | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 0.3 | 0.3 | 0.6 | 2.2 | 3.3 | 2.5 |
| ACIDITY | | | | | | | |
| IN KCl exchange acidity | | | | | | | |
| Total | (me/100g) | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | |
| CATION EXCHANGE CAPACITY NaOAc@pH 8.2 | (me/100g) | 19.1 | 20.0 | 18.7 | 28.8 | 20.2 | 16.6 |
| BORON | (mg/l) | | | | | | |

Table 15

GPO 833-276

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Reclamation Area: White Tail Butte
Location. Sec. 30 Twp. 56N Range 72W
1400' E., 120' N., SW cor.; Profile #24
Climate: Continental - semiarid
Land Use: Range

Relief: Normal
Elevation: 4020'
Slope: Aspect: N
Vegetation: Mid and short grasses with big sage
Erosion: Slight-sheet

Stoniness: None
Drainage: Well drained (surface)
Ground Water: None
Land Form: Colluvial slope

Parent Material: Baked rock
Soil Series: Bidman
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | PROFILE DESCRIPTION | |
|---|---|---|---|
| | 0 - .05 | (A1 | A light brownish gray 10YR 6/2 silt loam, dark grayish brown 10YR 4/2 when moist; fine blocky structure parting to medium crumb; soft when dry, very friable when moist; nonsticky and nonplastic when wet; noncalcareous; few roots; abrupt boundary. |
| 6919 T914 | .05 - .10 | (AB | A grayish brown 10YR 5/2 clay loam, dark brown 10YR 4/3 when moist; medium blocky structure parting to fine blocky; slightly hard when dry, friable when moist; a few thin discontinous clay films; slightly sticky and slightly plastic when wet; few roots; noncalcareous; gradual boundary. |
| | .10 - .18 | (B21t | A grayish brown 10YR 5/2 silty clay loam, dark grayish brown 10YR 4/2 when moist; medium prismatic structure parting to fine blocky; sticky and plastic when wet; noncalcareous; numerous thick clay films; few roots; gradual boundary. |
| | .18 - .38 | (B22t | A brown 10YR 5/3 silty clay, dark grayish brown 10YR 4/2 when moist; medium prismatic structure parting to medium blocky; numerous thick clay skins; hard when dry, friable when moist; very sticky and very plastic when wet; noncalcareous; few roots; gradual boundary. |
| 6920 T915 | .38 - .48 | (B3ca | A grayish brown 10YR 5/2 silty clay loam, dark grayish brown 10YR 4/2 when moist; coarse prismatic structure parting to coarse blocky; very hard when dry, friable when moist; sticky and plastic when wet; moderately calcareous; few roots; abrupt boundary. |
| 6921 T916 | .48 - 1.1 | C1ca | A pale brown 10YR 6/3 silty clay loam, brown 10YR 4/3 when moist; very coarse blocky structure parting to coarse blocky; hard when dry, friable when moist; sticky and plastic when wet; moderatley calcareous; occasional roots; gradual boundary. |
| 6922 T917 | 1.1 - 1.5 | C2ca | A brown 7.5YR 5/4 loam, dark brown 10YR 4/4 when moist; massive; slightly hard when dry, very friable when moist; nonsticky and nonplastic when wet; moderately calcareous; few roots; gradual boundary. |
| 6923 T918 | 1.5 - 1.8 | IIC3ca | A light brown coarse sandy loam, brown 10YR 5/4 when moist; massive; loose dry, loose moist; nonsticky and nonplastic when wet; moderatley calcareous; baked rock fragments 25-50 percent. |

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 6919 | 6920 | 6921 | 6922 | 6923 |
| DEPTH | (cm) | 0-.18 | .18-.48 | .48-1.1 | 1.1-1.5 | 1.5-1.8 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | | | | | |
| Coarse Sand | (1.0-0.5mm) | | | | | |
| Medium Sand | (0.5-0.25mm) | | | | | |
| Fine Sand | (0.25-0.10mm) | | | | | |
| Very Fine Sand | (0.10-0.05mm) | | | | | |
| Total Sand | (2.0-0.05mm) | 24.0 | 14.1 | 20.0 | 28.7 | 60.8 |
| Silt | (0.05-0.002mm) | 41.5 | 43.3 | 41.5 | 45.1 | 31.4 |
| Clay | (<0.002mm) | 34.5 | 42.6 | 38.5 | 26.2 | 07.8 |
| TEXTURAL CLASS (LAB) | | Cl | SiC | SiCl | L | CoSl |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | |
| 6th hr | | 5.1 | 1.2 | 0.89 | 1.2 | 3.6 |
| 24th hr | | 4.8 | 2.0 | 0.86 | 1.2 | 3.6 |
| SETTLING VOLUME | (ml) | 26 | 26 | 25 | 23 | 22 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | 33.7 | 39.6 | 36.5 | 35.0 | 35.5 |
| 1/3 bar | | 25.8 | 28.6 | 27.1 | 25.0 | 23.4 |
| 15 bar | | 16.1 | 17.6 | 13.9 | 12.0 | 9.93 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 6.8 | 7.0 | 8.5 | 8.3 | 8.2 |
| 1:2 0.01 M $CaCl_2$ | | 6.6 | 6.7 | 7.8 | 7.9 | 8.0 |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.1 | -0.4 | -0.4 | -12. | -13. |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 53.2 | 62.5 | 57.1 | 55.9 | 45.8 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.54 | 0.56 | 0.62 | 7.0 | 11.0 |
| $Ca^{++}$ | (me/l) | 3.24 | 3.79 | 0.88 | 23.55 | 25.00 |
| $Mg^{++}$ | (me/l) | 2.08 | 2.80 | 2.53 | 92.52 | 146.3 |
| $Na^{+}$ | (me/l) | 0.29 | 0.33 | 3.54 | 26.09 | 38.65 |
| $K^{+}$ | (me/l) | 0.38 | 0.10 | 0.10 | 0.61 | 0.86 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 3.96 | 3.32 | 4.20 | 1.48 | 2.12 |
| $Cl^{-}$ | (me/l) | 0.20 | 0.20 | 0.52 | 3.40 | 6.84 |
| $SO_4^{-}$ | (me/l) | 0.96 | 2.87 | 1.00 | 137. | 214. |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.02 | 0.10 | 0.09 | 0.15 |
| SAR | (me/l) | 0.2 | 0.2 | 2.7 | 3.4 | 4.2 |
| Na | (me/100g) | 0.02 | 0.02 | 0.20 | 1.46 | 1.77 |
| Ca+Mg | (me/100g) | 0.28 | 0.42 | 0.19 | 6.49 | 7.85 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.10 | 0.22 | 0.40 | 3.6 | 3.5 |
| Ca+Mg | (me/l) | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 0.3 | 0.3 | 2.1 | 3.0 | 9.4 |
| ACIDITY | | | | | | |
| 1N KCl exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 21.4 | 26.8 | 20.0 | 17.8 | 14.5 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 16

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Reclamation Area: White Tail Butte
Location. Sec. 25 Twp. 56N Range 73W
NW¼ SW¼ Profile #28
Climate: Continental semiarid
Land Use: Range

Relief: Normal
Elevation: 4140'
Slope: Aspect: SW
Vegetation: Mixed mid and short grass with sage
Erosion:

Stoniness: None
Drainage: Surface - well drained
Ground Water: None
Land Form: Alluvial Fan

Parent Material: Fort Union
Soil Series: Fort Collins
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/76

| LAB NO. | DEPTH (M) | | PROFILE DESCRIPTION |
|---|---|---|---|
| | | A1 | A light brownish gray 10YR 6/2 silt loam, dark brown 10YR 4/3 when moist; fine crumb structure; slightly hard when dry, friable when moist; nonsticky and nonplastic when wet; noncalcareous; many roots; gradual boundary. |
| | | B12 | A brown 10YR 5/3 silty clay loam, dark grayish brown 10YR 4/2 when moist; medium prismatic structure; hard when dry, friable when moist; sticky and plastic when wet; noncalcareous; many roots; abrupt boundary. |
| T894 | 0 - .5 | B22t | A brown 10YR 5/3 silty clay loam, dark brown 10YR 4/3 when moist; medium prismatic structure; very hard when dry, friable when moist; very sticky and very plastic when wet; noncalcareous; many roots; abrupt boundary. |
| | | B3 | A brown 10YR 5/3 silty clay loam, dark grayish brown 10YR 4/3 when moist; coarse prismatic structure; very hard when dry, friable when moist; slightly sticky and slightly plastic when wet; noncalcareous; many roots; abrupt boundary. |
| T895 | .5 - .9 | C1ca | A light brownish gray 10YR 6/2 silty clay loam, yellowish brown 10YR 5/4 when moist; very coarse to coarse medium blocky structure; very hard when dry, friable when moist; slightly sticky and slightly plastic when wet; calcareous; few roots, gradual boundary. |
| T896 | .9 - 1.4 | C2ca | A pale brown 10YR 6/3 silty clay loam, yellowish brown 10YR 5/4 when moist; very coarse blocky to coarse medium blocky structure; slightly hard when dry, firable when moist; slightly sticky and slightly plastic when wet; calcareous; few roots; abrupt boundary. |
| T897 | 1.4 - 2.0 | C3ca | A light gray 10YR 7/2 clay loam, pale brown 10YR 6/3 when moist; mottling is strong brown 7.5YR 5/6; consolidated firm sandy shale; very hard when dry, very friable when moist; slightly sticky and slightly plastic when wet; calcareous; few roots; abrupt boundary. |
| T898 | 2.0 - 2.6 | C4 | A pinkish gray 7.5YR 7/2 silty clay loam, brown 7.5YR 5/2 when moist; consolidated firm sandy shale; extremely hard when dry and firm when moist; slightly sticky and slightly plastic when wet; calcareous; no roots; gradual boundary. |
| T899 | 2.6 - 3.0 | C5 | A light gray 10YR 7/2 clay loam, light brownish gray 10YR 6/2 when moist; consolidated firm sandy shale; extremely firm when moist; slightly sticky and slightly plastic when wet; calcareous; non roots. |

This soil represents the deep alluvial soils. They formed in fine loamy alluvium on fans and in bench positions. The native vegetation is grass, blue grama, green needle, western wheat, and prairie june with big sage and forbes. Rill and gully erosion is moderate around edge of delineation.

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | |
|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | T894 | T895 | T896 | T897 | T898 | T899 |
| DEPTH | (cm) | 0-.5 | .5-.9 | .9-1.4 | 1.4-2.0 | 2.0-2.6 | 2.6-3.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | | |
| Total Sand | (2.0-0.05 mm) | 19.4 | 19.6 | 17.0 | 29.4 | 18.4 | 23.7 |
| Silt | (0.05-0.002 mm) | 53.2 | 48.4 | 45.7 | 39.8 | 49.1 | 47.6 |
| Clay | (<0.002 mm) | 27.4 | 32.0 | 37.3 | 30.8 | 32.5 | 28.7 |
| TEXTURAL CLASS (LAB.) | | SiCl | SiCl | SiCl | Cl | SiCl | Cl |
| BULK DENSITY | ($g/cm^3$) | | | | | | |
| HYDRAULIC CONDUCTIVITY | (cm/hr) | | | | | | |
| 6th hr | | 1.6 | 1.7 | 1.2 | 1.3 | 1.8 | 1.1 |
| 24th hr | | 1.5 | 1.6 | 1.2 | 1.3 | 1.7 | 1.1 |
| SETTLING VOLUME | (ml) | 24 | 24 | 25 | 24 | 26 | 25 |
| MOISTURE RETENTION | (percent) | | | | | | |
| 1/10 bar | | 29.3 | 32.1 | 32.0 | 29.6 | 33.2 | 33.2 |
| 1/3 bar | | 22.9 | 25.7 | 26.6 | 28.2 | 27.3 | 27.1 |
| 15 bar | | 12.5 | 13.9 | 15.3 | 13.2 | 16.0 | 15.2 |
| SOIL REACTION-pH | | | | | | | |
| Paste | | | | | | | |
| 1:5 $H_2O$ | | 7.2 | 8.7 | 8.7 | 8.3 | 7.9 | 7.9 |
| 1:2 0.01 M $CaCl_2$ | | 6.8 | 8.1 | 7.9 | 7.9 | 7.7 | 7.7 |
| ORGANIC CARBON | (percent) | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.1 | -0.4 | -0.4 | -3.7 | -13 | -8.6 |
| SATURATION EXTRACT | | | | | | | |
| Saturation Percentage | | 19.2 | 54.7 | 59.2 | 57.0 | 60.3 | 62.6 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.84 | 0.74 | 1.4 | 6.0 | 7.0 | 5.5 |
| $Ca^{++}$ | (me/l) | 4.23 | 1.26 | 2.03 | 15.92 | 26.10 | 25.40 |
| $Mg^{++}$ | (me/l) | 3.98 | 2.71 | 7.60 | 38.57 | 48.77 | 35.77 |
| $Na^{+}$ | (me/l) | 1.48 | 4.96 | 12.52 | 25.35 | 27.26 | 20.00 |
| $K^{+}$ | (me/l) | 0.22 | 0.10 | 0.22 | 0.50 | 0.77 | 0.76 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 6.76 | 4.28 | 3.44 | 2.08 | 1.84 | 1.68 |
| $Cl^{-}$ | (me/l) | 0.12 | 1.92 | 8.12 | 12.24 | 11.20 | 4.64 |
| $SO_4^{-}$ | (me/l) | 1.52 | 1.80 | 9.60 | 65.4 | 87.9 | 70.4 |
| $NO_3^{-}$ | (me/l) | 0.02 | 0.06 | 0.08 | 0.05 | 0.06 | 0.05 |
| SAR | (me/l) | 0.7 | 3.5 | 5.7 | 4.9 | 4.5 | 3.6 |
| Na | (me/100g) | 0.07 | 0.27 | 0.74 | 1.44 | 1.64 | 1.25 |
| Ca+Mg | (me/100g) | 0.42 | 0.22 | 0.57 | 3.11 | 3.69 | 3.83 |
| 1:5 EXTRACT | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.16 | 0.20 | 0.44 | 1.1 | 3.2 | 2.8 |
| Ca+Mg | (me/l) | | | | | | |
| EXCHANGEABLE SODIUM | (percent) | 2.2 | 3.5 | 4.4 | 2.5 | 1.9 | 1.9 |
| ACIDITY | | | | | | | |
| IN KCl exchange acidity | | | | | | | |
| Total | (me/100g) | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 16.7 | 22.1 | 18.7 | 15.7 | 18.5 | 17.0 |
| NaOAc@pH 8.2 | | | | | | | |
| BORON | (mg/l) | | | | | | |

Table 17

Table 20 - Suitability of Bedrock Material for Use as Plant Media for Revegetation - White Tail Butte Study Area, Wyoming

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 101-1 | 0.0-13.0 | Sh<br>Css | Limited Suitability | Clay-salinity |
| 101-2 | 13.0-25.1 | Sh | Limited Suitability | Clay-acidity |
| | 25.1-27.3 | Coal | | |
| 101-3 | 27.3-40.8 | C Sist<br>SiSh | Suitable | |
| 101-4 | 40.8-45.8 | SiSs<br>SiSh | Suitable | |
| 101-5 | 45.8-60.6 | SiSs | Suitable | |
| 101-6 | 60.6-135.9 | Sh | Limited Suitability | Clay-perm |
| | 135.9-136.8 | Lime-stone | Limited Suitability | Indurated 1/ |
| | 136.8-163.8 | Sh | Limited Suitability | Clay-perm |
| 101-7 | 163.8-170.1 | Sh | Limited Suitability | Clay-perm |
| | 170.1-207.9 | Coal | | |
| 101-8 | 207.9-214.0 | CbSh | Unsuitable | Swelling clay |
| | 214.0-240.2 | Coal | | |
| 101-9 | 240.2-265.3 | Sh/<br>SiSh<br>SiSs | Unsuitable | Clay-perm |
| | 265.3-268.1 | CbSh | Unsuitable | Clay-perm |
| | 268.1-289.3 | Coal | | |
| | 289.3-298.2 | CbSh | Unsuitable | Clay-perm |
| 101-10 | 298.2-319.6 | Sh/<br>Coal<br>SiSs, composite sample | Unsuitable | Clay-perm |

1/ Mining procedures would not separate the limestone.

Sh - shale
CbSh - carbonaceous shale
Ss - sandstone
SiSt - Siltstone
Cec - Cation exchange capacity
SiSh - silty shale
Sst - sandy siltstone
SiSs - silty sandstone
Css - clayey sandstone
C Sist - clayey siltstone
S Sist - sandy siltstone
/ - with
BR - baked rock
SSh - sandy shale

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 102-1 | 0.0-18.0 | C Sist | Limited Suitability | Clay-perm |
| 102-2 | 18.0-41.0 | Sh | Limited Suitability | Clay-perm |
| | 41.0-43.2 | Coal | | |
| 102-3 | 43.2-60.0 | Sh | Suitable | |
| | | Ss | | |
| 102-4 | 60.0-68.9 | Ss | Suitable | |
| 102-5 | 68.9-99.0 | Sh | Limited Suitability | Clay-perm |
| | 99.0-101.0 | SiSs | Limited Suitability | Clay-perm |
| 102-6 | 101.0-136.4 | SiSh | Limited Suitability | Clay-perm |
| 102-7 | 136.4-182.8 | Sh | Unsuitable | Swelling clay |
| 102-8 | 182.8-211.9 | Sh | Unsuitable | Swelling clay |
| | 211.9-248.5 | Coal | | |
| 102-9 | 248.5-253.0 | Sh | Unsuitable | Swelling clay |
| | 253.0-281.2 | Coal | | |
| 102-10 | 281.2-295.3 | Sh | Unsuitable | Swelling clay |
| | | SiSs | | |
| | 295.3-317.8 | Coal | | |
| 102-11 | 317.8-348.2 | Layer of CbSh Coal & Sh | Unsuitable | Swelling clay |

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 103-1 | 0.0-24.5 | SiSh | Suitable | |
| 103-2 | 24.5-30.8 | SiSh | Suitable | |
| | 30.8-32.0 | Coal | | |
| 103-3 | 32.0-50.5 | Sh | Limited Suitability | Clay-carbonaceous material |
| | 50.5-83.0 | Coal | | |
| | 83.0-91.5 | CbSh | Unsuitable | Clay1/ |
| 103-4 | 91.5-109.2 | Sh | Unsuitable | Swelling clay |
| 103-5 | 109.2-133.0 | Sh/ Coal | Unsuitable | Swelling clay/coal |
| 103-6 | 133.0-153.0 | Sh/ Coal SiSh | Unsuitable | Swelling clay/coal |
| 103-7 | 172.2-182.2 | Ss SiSh Sh | Unsuitable | Swelling clay |
| | 182.2-203.0 | Coal | | |
| | 203.0-208.4 | Sh SiSt | Unsuitable | Swelling clay |
| | 208.4-213.8 | Coal | | |
| 103-8 | 213.8-233.0 | Sh/ Coal | Unsuitable | Swelling clay |

1/ Too thin to separate from coal.

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 104-1 | 0.0-8.5 | Sh | Limited Suitability | Clay-salinity |
| 104-2 | 8.5-12.5 | Ss | Suitable | |
| | 12.5-14.0 | Sh | Unsuitable | Clay-perm |
| | 14.0-15.3 | Limestone | | Indurated |
| 104-3 | 15.3-23.5 | SiSh<br>SiSs | Limited Suitability | Clay-salinity |
| 104-4 | 23.5-53.5 | SiSh | Limited Suitability | Clay-perm |
| 104-5 | 53.5-102.8 | SiSh | Limited Suitability | Clay-perm |
| 104-6 | 102.8-153.3 | SSh<br>SiSs<br>SiSh | Limited Suitability | Clay-perm |
| | 153.3-162.7 | Ss | Limited Suitability | 1/ |
| 104-7 | 162.7-203.3 | Css<br>SSh | Limited Suitability | Clay-perm |
| | 203.3-204.5 | Css<br>SSh | Limited Suitability | Clay-perm |
| 104-8 | 204.5-222.0 | SiSs<br>SiSh | Limited Suitability | Clay-perm |
| 104-9 | 222.0-234.0 | Sh<br>SSh | Limited Suitability | Clay-perm |
| | 234.0-239.0 | Sh<br>SSh | Limited Suitability | Clay-perm |
| | 239.0-240.5 | Lime-<br>stone | Unsuitable | Indurated |
| | 240.5-245.0 | Css | Unsuitable | 1/ |
| 104-10 | 245.0-255.0 | Sh | Unsuitable | Swelling clay |
| 104-11 | 255.0-263.5 | SSh<br>SiSh | Unsuitable | 1/ |
| 104-12 | 263.5-274.0 | Sh | Unsuitable | Clay-perm |
| 104-13 | 274.0-283.6 | Sh/<br>Coal | Unsuitable | Swelling clay/coal |
| | 283.6-287.5 | Sh | Unsuitable | Swelling clay |
| 104-14 | 287.5-294.0 | Sh | Unsuitable | Clay-acidity |
| | 294.0-315.5 | Coal | | |
| 104-15 | 315.5-321.9 | Sh | Unsuitable | Swelling clay |
| | 321.9-343.0 | Coal | | |
| 104-16 | 343.0-356.5 | Sh | Unsuitable | Swelling clay |

1/ Too thin to separate from interbedded clay rich shales.

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 105-1 | 0.0-2.5 | SiSh | Suitable | |
| | 2.5-10.0 | SiSh | Limited Suitability | Unstable silts/clay |
| | 10.0-45.5 | SiSh | Unsuitable | Clay-indurated silt |
| 105-2 | 47.8-67.5 | CbSh | Unsuitable | Carbonaceous clay |
| | 67.5-72.0 | Coal | | |
| | 72.0-98.3 | Coal | | |
| 105-3 | 98.3-113.5 | Sh | Unsuitable | Clay-perm |
| 105-4 | 113.5-133.5 | Sh | Unsuitable | 1/ |
| | | Ss | | |
| 105-5 | 133.5-175.0 | Sh | Unsuitable | Swelling clay |
| | | Ss | | |
| 105-6 | 175.0-185.0 | CbSh | Unsuitable | Swelling clay |
| | 185.0-204.3 | Coal | | |
| 105-7 | 204.3-229.6 | Sh | Unsuitable | Swelling clay |
| | | Ss | | |
| | | SSh | | |
| | 229.6-239.5 | Alternating Sh & Ss | | Clay-perm |
| | 239.5-259.0 | Coal | | |
| 105-8 | 259.0-275.0 | Sh | Unsuitable | Swelling clay |
| | | SSh | | |

1/ Thin sandstone layers are too thin to warrant separation at this depth.

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 106-1 | 0.0-27.0 | Sh | Limited Suitability | Clay-salinity |
| 106-2 | 27.0-38.8 | Sh<br>Ss | Suitable | |
| 106-3 | 38.8-84.7 | Sh | Unsuitable | Clay |
| 106-4 | 84.7-106.8 | Sh/<br>Coal | Unsuitable | Swelling clay-coal |
| | 106.8-140.4 | Coal | | |
| 106-5 | 140.4-161.0 | Sh | Unsuitable | Swelling clay |
| 106-6 | 161.0-169.4 | Sh<br>Css | Unsuitable | Swelling clay |
| 106-7 | 169.4-214.0 | Ss<br>Sh | Unsuitable | Swelling clay1/ |
| | 214.0-215.3 | Ss | | |
| 106-8 | 215.3-287.0 | Sh/<br>SSh<br>Ss | Unsuitable | Swelling clay1/ |

1/ Sandstone layers too thin to separate.

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 107-1 | 0.0-14.0 | Sh | Limited Suitability | Clay-salinity |
| | 14.0-26.4 | SiSs | Suitable | |
| | 26.4-32.0 | SiSt/ Coal | Unsuitable | Indurated/coal |
| 107-2 | 32.0-73.6 | Sh | Limited Suitability | Clay-perm |
| 107-3 | 73.6-84.1 | SiSs | Suitable | |
| 107-4 | 84.1-111.0 | Sh | Limited Suitability | Clay-perm |
| | 111.0-130.3 | Sh | Unsuitable | Clay-perm |
| | 130.3-165.0 | Coal | | |
| 107-5 | 165.0-176.0 | Sh | Unsuitable | Clay |
| 107-6 | 176.0-187.0 | Css SiSs | Limited Suitability | Swelling silt & sand |
| 107-7 | 187.0-215.4 | SiSh SiSs | Unsuitable | Swelling clay |
| 107-8 | 215.4-220.0 | Ss | Unsuitable | Swelling clay |
| | 220.0-226.0 | Ss Sh | Limited Suitability | 1/ |
| | 226.0-235.0 | Ss Sh | Unsuitable | Swelling clay |
| 107-9 | 235.0-242.0 | Ss Sh | Limited Suitability | 1/ |
| 107-10 | 242.0-279.3 | Ss Sh | Unsuitable | Swelling clay |
| 107-11 | 279.3-284.9 | SiSh SiSs | Unsuitable | Swelling clay |
| 107-12 | 284.9-327.1 | Sh | Unsuitable | Swelling clay |
| | 327.1-331.9 | Coal | | |
| 107-13 | 331.9-335.1 | SiSs SiSh | Unsuitable | Clay-acidity |
| | 335.1-348.2 | Coal | | |
| 107-14 | 348.2-353.1 | Sh | Unsuitable | Swelling clay |
| | 353.1-378.2 | Coal | | |
| 107-15 | 378.2-401.0 | SiSh | Unsuitable | Swelling clay |

1/ Siltstone and sandstone may be too thin to warrant separation at this depth.

| Core No. | Depth Feet | Type | Suitability Classification | Deficiency |
|---|---|---|---|---|
| 108-1 | 0.0-16.5 | Sh | Unsuitable | Clay-salinity |
| | 16.5-21.5 | Sh | Suitable | |
| | 21.5-24.3 | Sh | Unsuitable | Clay-perm |
| 108-2 | 24.3-41.5 | SiSt<br>SiSh | Limited Suitability | Clay-perm |
| 108-3 | 41.5-50.0 | SiSt | Suitable | |
| 108-4 | 50.0-70.0 | Sh | Unsuitable | Clay/coal |
| | 10.0-100.5 | Coal | | |
| | 100.5-104.5 | Sh/Coal | Unsuitable | Clay/coal |
| 108-5 | 104.5-120.0 | SSh<br>SiSh | Unsuitable | Clay-perm |
| 108-6 | 120.0-144.0 | SiSh<br>SiSs | Limited Suitability | Clay-perm |
| | 144.0-174.0 | SiSs | Limited Suitability | Unstable sand |
| 108-7 | 174.0-200.0 | SiSs | Unsuitable | 1/ |
| 108-8 | 200.0-254.0 | Sh | Unsuitable | Swelling clay |
| | 254.0-263.5 | Sh/Coal | Unsuitable | Swelling clay |
| 108-9 | 263.5-269.5 | SiSs | Unsuitable | Swelling clay |
| | 269.5-282.9 | Coal | | |
| 108-10 | 282.9-307.5 | Ss<br>SiSs<br>SiSh | Unsuitable | Swelling clay |
| | 307.5-329.0 | Sh | Unsuitable | Swelling clay |
| 108-11 | 329.0-341.5 | Sh | Unsuitable | Swelling clay |

1/ Sample may not be representative. Materal may have limited suitability.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Table 21

WHITE TAIL BUTTE RECLAMATION AREA
TABLE 21 INTERPRETIVE RATINGS FOR SOIL USES

| Map Symbol (1) | Soil Name (2) | Suitability | | | | | | Degree of Limitation and Soil Features Affecting | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dryland Farming (3) | Irrigation (4) | Topsoil (5) | Sand/ Gravel (6) | Road Fill (7) | Other (8) | Ponds Location (9) | Ponds Embankment (10) | Road Location (11) | Shallow Excavations (12) | Building Sites (13) |
| 024-025 | Bidman-Brigsbale 0-6% | Good-Fair | Favorable | Good | None | Poor | Range Wildlife | Favorable | Good | Poor | Good | Poor |
| 024 | Bidman 0-6% | Good | Favorable | Good | None | Poor | Range Wildlife | Favorable | Good | Poor | Good | Poor |
| 012 | Cushman 3-6% | Favorable | Favorable | Fair | None | Poor | Range Wildlife | Favorable | Fair-Poor | Poor | Good | High bearing capacity |
| 012-030 | Cushman-Stoneham 3-6% | Favorable | Favorable | Fair | None | Poor | Range Wildlife | Favorable | Fair | Poor | Good | Poor |
| 012-034 | Cushman-Worf 6-15% | Severe Limitations | Shallow to Shale | Fair | None | Poor | Range Wildlife | Favorable | Fair | Poor | Shallow Steep | Poor |
| 029-034 | Shingle-Worf 0-10% | Severe Limitations | Shallow to Shale | Fair | None | Poor | Range Wildlife | Favorable | Fair | Poor | Shallow Steep | Poor |
| 027-012 | Fort Collins-Cushman 0-6% | Good to Favorable | Favorable | Good | None | Fair-Poor | Range Wildlife | Favorable | Good | Fair | Good | Poor |
| 029-032 | Shingle-Thedlund Rolling 10-30% | Not Suitable | Shallow to Shale | Fair | None | Poor | Range Wildlife | Favorable | Fair | Poor | Shallow Steep | Poor |
| 06 | Terrace Escarpment 8-35% | Not Suitable | Steep Slopes | Fair | None | Fair-Poor | Range Wildlife | Favorable | Fair-Poor | Poor | Shallow Steep | Poor |
| 028-033 | Sears-Wibaux 6-15% | Not Suitable | Shallow to Shale | Fair | None-Fair | Fair-Good | Range Wildlife | Shallow to Fractured Rock | Poor | Good-Fair | Shallow to Fractured Rock | Poor |
| 026 | Dillingson 2-6% | Good | Favorable | Good | None | Fair | Range Wildlife | Favorable | Fair-Poor | Fair | Good | Poor |
| 029-031 | Shingle-Samsil Gullied 15-60% | Not Suitable | Shallow to Shale | Fair | None | Poor | Range Wildlife | Favorable | Fair | Shallow Steep | Poor | Poor |
| 029-036 | Shingle Rolling 10-30% | Not Suitable | Shallow to Shale | Fair | None | Poor | Range Wildlife | Favorable | Fair | Shallow Steep | Poor | Poor |
| 033-029 | Wibaux-Shingle Rolling 6-45% | Not Suitable | Shallow to Shale | Fair | None | Fair-Poor | Range Wildlife | Mod. Deep to Fractured Rock | Poor | Shallow Steep | Poor | Poor |
| 035-029 | Hamstone-Shingle 6-15% | Not Suitable | Shallow to Shale | Good-Fair | None | Poor | Range Wildlife | Favorable | Fair | Shallow Steep | Poor | Poor |

# APPENDIX

## Table 22.--Data for defining moisture relations in soils

| M DEPTH | RETENTION FORCE | | VOLUME WEIGHT | AVERAGE VOLUME WEIGHT | SOIL MOISTURE | MOISTURE RETENTION CAPABILITY | ADSORPTION CAPACITY | VOID MOISTURE CAPACITY | SOIL MOISTURE | VOID MOISTURE CAPACITY | PERMEABILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M | G/SQCM | PF | G/CC | G/CC | % | % | % | % | MOLECULAR LAYERS OF WATER | MOLECULAR LAYERS OF WATER | CM/HR |
| WHTE SITE 1 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 15132. | 4.18 | 1.02 | 1.02 | 14.22 | 24.86 | 42.98 | 60.28 | 5.3 | 22.4 | 2.3 |
| 0.20 | 13849. | 4.14 | 1.21 | 1.19 | 13.02 | 24.15 | 38.64 | 46.00 | 5.4 | 19.0 | 2.1 |
| 0.30 | 14150. | 4.15 | 1.35 | 1.29 | 12.39 | 23.08 | 36.94 | 40.01 | 5.4 | 17.3 | 2.0 |
| 0.40 | 17470. | 4.24 | 1.30 | 1.35 | 11.95 | 23.28 | 37.24 | 36.21 | 5.1 | 15.6 | 1.9 |
| 0.50 | 12385. | 4.09 | 1.41 | 1.41 | 11.68 | 21.18 | 33.88 | 33.37 | 5.5 | 15.8 | 1.9 |
| 0.60 | 12120. | 4.08 | 1.52 | 1.45 | 11.58 | 20.91 | 33.46 | 31.04 | 5.5 | 14.8 | 1.8 |
| 0.70 | 14547. | 4.16 | 1.44 | 1.40 | 13.23 | 24.79 | 39.66 | 33.63 | 5.3 | 13.6 | 1.7 |
| 0.80 | 11835. | 4.07 | 1.25 | 1.31 | 13.68 | 24.57 | 39.31 | 39.45 | 5.6 | 15.6 | 1.9 |
| 0.90 | 10878. | 4.04 | 1.25 | 1.27 | 13.77 | 24.33 | 38.93 | 41.18 | 5.7 | 16.9 | 1.9 |
| 1.00 | 19907. | 4.30 | 1.30 | 1.36 | 13.06 | 26.18 | 41.89 | 35.89 | 5.0 | 13.7 | 1.7 |
| 1.10 | 24691. | 4.39 | 1.52 | 1.52 | 12.65 | 26.64 | 42.63 | 28.03 | 4.7 | 10.5 | 1.5 |
| 1.20 | 35873. | 4.55 | 1.74 | 1.57 | 12.66 | 29.23 | 46.76 | 25.98 | 4.3 | 8.9 | 1.4 |
| 1.30 | 41362. | 4.62 | 1.45 | 1.59 | 12.96 | 31.06 | 49.69 | 25.09 | 4.2 | 8.1 | 1.4 |
| 1.40 | 25579. | 4.41 | 1.59 | 1.63 | 12.49 | 26.52 | 42.43 | 23.79 | 4.7 | 9.0 | 1.5 |
| 1.50 | 28051. | 4.45 | 1.84 | 1.65 | 12.46 | 27.04 | 43.27 | 22.76 | 4.6 | 8.4 | 1.4 |
| 1.60 | 35023. | 4.54 | 1.53 | 1.73 | 12.48 | 28.64 | 45.82 | 20.10 | 4.4 | 7.0 | 1.3 |
| 1.70 | 27697. | 4.44 | 1.82 | 1.61 | 12.28 | 26.57 | 42.51 | 24.27 | 4.6 | 9.1 | 1.5 |
| 1.80 | 28454. | 4.45 | 1.49 | 1.67 | 12.10 | 26.36 | 42.17 | 22.32 | 4.6 | 8.5 | 1.4 |
| 1.90 | 31414. | 4.50 | 1.69 | 1.64 | 11.76 | 26.26 | 42.01 | 23.26 | 4.5 | 8.9 | 1.4 |
| 2.00 | 34354. | 4.54 | 1.74 | 1.64 | 11.49 | 26.22 | 41.95 | 23.31 | 4.4 | 8.9 | 1.4 |
| 2.10 | 21691. | 4.34 | 1.49 | 1.74 | 11.86 | 24.24 | 38.79 | 19.43 | 4.9 | 8.1 | 1.4 |
| 2.20 | 4114A. | 4.61 | 2.01 | 1.88 | 11.49 | 27.49 | 43.99 | 15.48 | 4.2 | 5.6 | 1.2 |
| 2.30 | 2803A. | 4.45 | 2.15 | 2.04 | 11.19 | 24.28 | 38.85 | 11.24 | 4.6 | 4.6 | 1.2 |
| 2.40 | 27884. | 4.45 | 1.97 | 1.97 | 11.83 | 25.65 | 41.04 | 12.97 | 4.6 | 5.1 | 1.2 |
| WHTE SITE 2 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 1466A. | 4.17 | 1.13 | 1.13 | 12.23 | 22.96 | 36.74 | 50.82 | 5.3 | 22.1 | 2.3 |
| 0.20 | 23315. | 4.37 | 1.42 | 1.43 | 13.13 | 27.28 | 43.65 | 32.12 | 4.8 | 11.8 | 1.6 |
| 0.30 | 28143. | 4.45 | 1.74 | 1.54 | 12.44 | 27.03 | 43.24 | 27.01 | 4.6 | 10.0 | 1.5 |
| 0.40 | 21523. | 4.33 | 1.47 | 1.60 | 12.60 | 25.71 | 41.14 | 24.90 | 4.9 | 9.7 | 1.5 |
| 0.50 | 23804. | 4.36 | 1.58 | 1.52 | 12.36 | 25.62 | 41.31 | 27.95 | 4.8 | 10.8 | 1.6 |
| 0.60 | 28332. | 4.45 | 1.52 | 1.58 | 12.47 | 27.14 | 43.42 | 25.75 | 4.6 | 9.5 | 1.5 |
| 0.70 | 18179. | 4.26 | 1.63 | 1.58 | 11.98 | 23.55 | 37.68 | 25.40 | 5.1 | 10.8 | 1.6 |
| 0.80 | 23660. | 4.37 | 1.61 | 1.64 | 11.67 | 24.34 | 38.94 | 23.33 | 4.8 | 9.6 | 1.5 |
| 0.90 | 2751A. | 4.44 | 1.68 | 1.62 | 11.27 | 24.36 | 38.97 | 23.94 | 4.6 | 9.8 | 1.5 |
| 1.00 | 23536. | 4.37 | 1.58 | 1.58 | 11.10 | 23.13 | 37.00 | 25.73 | 4.8 | 11.1 | 1.6 |
| 1.10 | 2868A. | 4.46 | 1.47 | 1.52 | 10.21 | 22.28 | 35.65 | 28.21 | 4.6 | 12.7 | 1.7 |
| 1.20 | 33870. | 4.53 | 1.50 | 1.47 | 10.37 | 23.60 | 37.75 | 30.19 | 4.4 | 12.8 | 1.7 |
| 1.30 | 24752. | 4.39 | 1.45 | 1.45 | 10.72 | 22.59 | 36.15 | 31.18 | 4.7 | 13.8 | 1.7 |
| 1.40 | 26475. | 4.42 | 1.41 | 1.46 | 9.66 | 21.12 | 33.79 | 30.55 | 4.7 | 14.5 | 1.8 |
| 1.50 | 26387. | 4.42 | 1.54 | 1.48 | 9.66 | 20.66 | 33.06 | 29.94 | 4.7 | 14.5 | 1.8 |
| 1.60 | 29385. | 4.47 | 1.49 | 1.55 | 9.20 | 20.21 | 32.33 | 26.72 | 4.6 | 13.2 | 1.7 |
| 1.70 | 24162. | 4.38 | 1.63 | 1.55 | 9.73 | 20.40 | 32.63 | 26.59 | 4.8 | 13.0 | 1.7 |
| 1.80 | 2910A. | 4.46 | 1.55 | 1.56 | 10.74 | 23.53 | 37.66 | 26.18 | 4.6 | 11.1 | 1.6 |
| 1.90 | 29807. | 4.47 | 1.51 | 1.53 | 10.72 | 23.61 | 37.78 | 27.43 | 4.5 | 11.6 | 1.6 |
| 2.00 | 27851. | 4.44 | 1.54 | 1.56 | 11.30 | 24.48 | 39.17 | 26.57 | 4.6 | 10.9 | 1.6 |
| 2.10 | 22300. | 4.35 | 1.61 | 1.48 | 11.41 | 23.46 | 37.54 | 30.06 | 4.9 | 12.8 | 1.7 |
| 2.20 | 26794. | 4.43 | 1.27 | 1.51 | 11.42 | 24.52 | 39.24 | 28.33 | 4.7 | 11.6 | 1.6 |
| 2.30 | 23489. | 4.37 | 1.65 | 1.53 | 12.38 | 25.77 | 41.24 | 27.47 | 4.8 | 10.7 | 1.6 |
| 2.40 | 22568. | 4.35 | 1.67 | 1.67 | 12.65 | 26.09 | 41.75 | 22.04 | 4.8 | 8.4 | 1.4 |

Table 22.--Data for defining moisture relations in soils--Continued

| M DEPTH | RETENTION FORCE | VOLUME WEIGHT | AVERAGE VOLUME WEIGHT | SOIL MOISTURE | MOISTURE RETENTION CAPABILITY | ABSORPTION CAPACITY | VOID MOISTURE CAPACITY | SOIL MOISTURE | VOID MOISTURE CAPACITY | PERMEABILITY |
|---|---|---|---|---|---|---|---|---|---|---|
| M | G/30CM PF | G/CC | G/CC | % | % | % | % | MOLECULAR LAYERS OF WATER | MOLECULAR LAYERS OF WATER | CM/HR |
| WHTE SITE 3 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | |
| 0.10 | 187. 2.27 | 0.92 | 0.92 | 24.53 | 24.09 | 38.55 | 71.30 | 10.2 | 29.6 | 2.7 |
| 0.20 | 6495. 3.81 | 1.32 | 1.27 | 14.64 | 23.48 | 37.57 | 40.81 | 6.2 | 17.4 | 2.0 |
| 0.30 | 16390. 4.21 | 1.58 | 1.48 | 11.55 | 22.20 | 35.51 | 29.75 | 5.2 | 13.4 | 1.7 |
| 0.40 | 17653. 4.25 | 1.54 | 1.60 | 11.00 | 21.47 | 34.36 | 24.89 | 5.1 | 11.6 | 1.6 |
| 0.50 | 18468. 4.27 | 1.66 | 1.67 | 10.86 | 21.41 | 34.26 | 22.09 | 5.1 | 10.3 | 1.5 |
| 0.60 | 19390. 4.29 | 1.91 | 1.68 | 11.21 | 22.35 | 35.77 | 21.70 | 5.0 | 9.7 | 1.5 |
| 0.70 | 16510. 4.22 | 1.58 | 1.72 | 11.33 | 21.81 | 34.89 | 20.55 | 5.2 | 9.4 | 1.5 |
| 0.80 | 18823. 4.27 | 1.76 | 1.61 | 11.22 | 22.22 | 35.56 | 24.53 | 5.1 | 11.0 | 1.6 |
| 0.90 | 11798. 4.07 | 1.48 | 1.64 | 11.77 | 21.14 | 33.82 | 23.31 | 5.6 | 11.0 | 1.6 |
| 1.00 | 13509. 4.13 | 1.67 | 1.53 | 11.88 | 21.93 | 35.09 | 27.72 | 5.4 | 12.6 | 1.7 |
| 1.10 | 16045. 4.21 | 1.43 | 1.57 | 13.75 | 26.30 | 42.08 | 25.77 | 5.2 | 9.8 | 1.5 |
| 1.20 | 13761. 4.14 | 1.62 | 1.66 | 14.16 | 26.24 | 41.98 | 22.48 | 5.4 | 8.6 | 1.4 |
| 1.30 | 17349. 4.24 | 1.93 | 1.67 | 11.55 | 22.46 | 35.94 | 22.10 | 5.1 | 9.9 | 1.5 |
| 1.40 | 13743. 4.14 | 1.46 | 1.60 | 11.69 | 21.45 | 34.64 | 24.70 | 5.4 | 11.4 | 1.6 |
| 1.50 | 19137. 4.28 | 1.42 | 1.45 | 13.01 | 25.86 | 41.38 | 31.16 | 5.0 | 12.0 | 1.6 |
| 1.60 | 13977. 4.15 | 1.48 | 1.50 | 12.50 | 23.22 | 37.15 | 28.95 | 5.4 | 12.5 | 1.7 |
| 1.70 | 16958. 4.23 | 1.60 | 1.54 | 13.38 | 25.89 | 41.43 | 27.23 | 5.2 | 10.5 | 1.5 |
| 1.80 | 20578. 4.31 | 1.54 | 1.59 | 14.74 | 29.76 | 47.62 | 25.34 | 5.0 | 8.5 | 1.4 |
| 1.90 | 15703. 4.20 | 1.62 | 1.59 | 16.33 | 31.10 | 49.76 | 25.31 | 5.3 | 8.1 | 1.4 |
| 2.00 | 16997. 4.23 | 1.60 | 1.59 | 14.59 | 28.25 | 45.20 | 25.05 | 5.2 | 8.9 | 1.4 |
| 2.10 | 18199. 4.26 | 1.56 | 1.57 | 13.73 | 26.98 | 43.18 | 25.79 | 5.1 | 9.6 | 1.5 |
| 2.20 | 14893. 4.17 | 1.56 | 1.61 | 13.82 | 26.02 | 41.63 | 24.37 | 5.3 | 9.4 | 1.5 |
| 2.30 | 18884. 4.28 | 1.71 | 1.66 | 11.71 | 23.21 | 37.13 | 22.67 | 5.0 | 9.8 | 1.5 |
| 2.40 | 16574. 4.22 | 1.69 | 1.69 | 9.56 | 18.42 | 29.47 | 21.36 | 5.2 | 11.6 | 1.6 |
| WHTE SITE 4 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | |
| 0.10 | 2430. 3.39 | 0.93 | 0.93 | 16.53 | 22.55 | 36.08 | 69.28 | 7.3 | 30.7 | 2.8 |
| 0.20 | 35317. 4.55 | 1.27 | 1.24 | 11.04 | 25.38 | 40.61 | 42.91 | 4.4 | 16.9 | 1.9 |
| 0.30 | 38999. 4.59 | 1.52 | 1.40 | 11.48 | 27.09 | 43.34 | 33.74 | 4.2 | 12.5 | 1.7 |
| 0.40 | 9396. 3.97 | 1.41 | 1.49 | 15.48 | 26.58 | 42.53 | 29.36 | 5.8 | 11.0 | 1.6 |
| 0.50 | 3342. 3.52 | 1.54 | 1.51 | 17.36 | 24.90 | 39.84 | 28.58 | 7.0 | 11.5 | 1.6 |
| 0.60 | 3189. 3.50 | 1.57 | 1.60 | 18.34 | 26.11 | 41.77 | 24.88 | 7.0 | 9.5 | 1.5 |
| 0.70 | 1341. 3.13 | 1.68 | 1.63 | 20.61 | 25.80 | 41.28 | 23.44 | 8.0 | 9.1 | 1.5 |
| 0.80 | 1170. 3.07 | 1.66 | 1.63 | 24.85 | 30.53 | 48.85 | 23.44 | 8.1 | 7.7 | 1.4 |
| 0.90 | 2527. 3.40 | 1.57 | 1.61 | 24.44 | 33.55 | 53.67 | 24.19 | 7.3 | 7.2 | 1.3 |
| 1.00 | 1735. 3.24 | 1.62 | 1.59 | 23.01 | 29.88 | 47.80 | 25.14 | 7.7 | 8.4 | 1.4 |
| 1.10 | 1477. 3.17 | 1.58 | 1.43 | 21.42 | 27.17 | 43.47 | 32.17 | 7.9 | 11.8 | 1.6 |
| 1.17 | 2260. 3.35 | 1.09 | 1.09 | 24.95 | 33.60 | 53.09 | 53.98 | 7.4 | 16.0 | 1.9 |
| WHTE SITE 5 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | |
| 0.10 | 190. 2.30 | 0.96 | 0.96 | 22.76 | 22.51 | 36.01 | 66.64 | 18.1 | 29.6 | 2.7 |
| 0.20 | 12594. 4.10 | 1.44 | 1.23 | 12.04 | 21.90 | 35.04 | 43.60 | 5.5 | 19.9 | 2.1 |
| 0.30 | 15160. 4.18 | 1.29 | 1.36 | 10.80 | 20.42 | 32.68 | 35.77 | 5.3 | 17.5 | 2.0 |
| 0.40 | 9493. 3.98 | 1.35 | 1.37 | 10.22 | 17.59 | 28.14 | 35.15 | 5.8 | 20.0 | 2.1 |
| 0.50 | 12978. 4.11 | 1.48 | 1.44 | 9.69 | 17.73 | 28.36 | 31.63 | 5.5 | 17.8 | 2.0 |
| 0.60 | 14930. 4.17 | 1.50 | 1.46 | 9.43 | 17.77 | 28.42 | 30.61 | 5.3 | 17.2 | 2.0 |
| 0.70 | 10797. 4.03 | 1.42 | 1.48 | 9.97 | 17.58 | 28.13 | 30.08 | 5.7 | 17.1 | 1.9 |
| 0.80 | 10168. 4.01 | 1.51 | 1.50 | 10.27 | 17.91 | 28.66 | 29.14 | 5.7 | 16.3 | 1.9 |
| 0.90 | 10378. 4.02 | 1.56 | 1.52 | 10.80 | 18.91 | 30.25 | 28.06 | 5.7 | 14.9 | 1.8 |
| 1.00 | 9587. 3.98 | 1.49 | 1.48 | 11.73 | 20.21 | 32.34 | 29.97 | 5.8 | 14.8 | 1.8 |
| 1.10 | 12438. 4.09 | 1.38 | 1.56 | 12.94 | 23.48 | 37.57 | 26.36 | 5.5 | 11.2 | 1.6 |
| 1.20 | 13350. 4.13 | 1.81 | 1.62 | 12.99 | 23.91 | 38.26 | 24.06 | 5.4 | 10.1 | 1.5 |
| 1.30 | 8311. 3.92 | 1.67 | 1.69 | 12.89 | 21.63 | 34.60 | 21.44 | 6.0 | 9.9 | 1.5 |
| 1.40 | 8648. 3.94 | 1.60 | 1.66 | 12.66 | 21.41 | 34.25 | 22.69 | 5.9 | 10.6 | 1.6 |
| 1.50 | 10015. 4.00 | 1.70 | 1.60 | 12.63 | 21.96 | 35.14 | 24.69 | 5.8 | 11.2 | 1.6 |
| 1.60 | 7834. 3.89 | 1.51 | 1.59 | 12.87 | 21.36 | 34.18 | 25.35 | 6.0 | 11.9 | 1.6 |
| 1.70 | 9421. 3.97 | 1.55 | 1.52 | 11.83 | 20.33 | 32.52 | 27.94 | 5.8 | 13.7 | 1.7 |
| 1.80 | 11894. 4.08 | 1.51 | 1.53 | 11.95 | 21.50 | 34.40 | 27.55 | 5.6 | 12.8 | 1.7 |
| 1.90 | 8437. 3.93 | 1.53 | 1.50 | 11.42 | 19.22 | 30.75 | 28.77 | 5.9 | 15.0 | 1.8 |
| 2.00 | 10061. 4.00 | 1.46 | 1.55 | 12.92 | 22.48 | 35.96 | 26.95 | 5.7 | 12.8 | 1.6 |
| 2.10 | 13234. 4.12 | 1.64 | 1.55 | 12.77 | 23.47 | 37.55 | 26.81 | 5.4 | 11.4 | 1.6 |
| 2.20 | 10316. 4.01 | 1.54 | 1.64 | 13.71 | 23.97 | 38.36 | 23.20 | 5.7 | 9.7 | 1.5 |
| 2.30 | 11661. 4.07 | 1.74 | 1.60 | 14.11 | 25.28 | 40.44 | 24.94 | 5.6 | 9.9 | 1.5 |
| 2.40 | 11546. 4.06 | 1.51 | 1.51 | 15.54 | 27.77 | 44.44 | 28.70 | 5.6 | 10.3 | 1.5 |

## Table 22.--Data for defining moisture relations in soils--Continued

| M DEPTH | RETENTION FORCE | | VOLUME WEIGHT | AVERAGE VOLUME WEIGHT | SOIL MOISTURE | MOISTURE RETENTION CAPABILITY | ADSORPTION CAPACITY | VOID MOISTURE CAPACITY | SOIL MOISTURE | VOID MOISTURE CAPACITY | PERMEABILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M | G/SQCM | PF | G/CC | G/CC | % | % | % | % | MOLECULAR LAYERS OF WATER | MOLECULAR LAYERS OF WATER | CM/HR |
| WHTE SITE 6 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 196. | 2.29 | 0.78 | 0.78 | 18.72 | 18.49 | 29.58 | 90.47 | 10.1 | 48.9 | 3.9 |
| 0.20 | 8637. | 3.94 | 0.92 | 0.96 | 6.73 | 11.38 | 18.21 | 66.41 | 5.9 | 58.3 | 4.4 |
| 0.30 | 10170. | 4.01 | 1.18 | 1.14 | 6.24 | 10.88 | 17.41 | 50.37 | 5.7 | 46.3 | 3.7 |
| 0.40 | 5547. | 3.74 | 1.30 | 1.27 | 7.19 | 11.21 | 17.94 | 41.32 | 6.4 | 36.9 | 3.1 |
| 0.50 | 7546. | 3.88 | 1.31 | 1.31 | 7.33 | 12.08 | 19.33 | 38.44 | 6.1 | 31.8 | 2.8 |
| WHTE SITE 7 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 6260. | 3.80 | 1.15 | 1.15 | 15.05 | 23.99 | 38.38 | 49.45 | 6.3 | 20.6 | 2.2 |
| 0.20 | 11086. | 4.04 | 1.12 | 1.22 | 12.51 | 22.19 | 35.50 | 44.54 | 5.6 | 20.1 | 2.1 |
| 0.30 | 12629. | 4.10 | 1.38 | 1.31 | 11.87 | 21.61 | 34.58 | 38.83 | 5.5 | 18.0 | 2.0 |
| 0.40 | 13168. | 4.12 | 1.42 | 1.43 | 11.51 | 21.12 | 33.80 | 32.19 | 5.4 | 15.2 | 1.8 |
| 0.50 | 10879. | 4.04 | 1.49 | 1.45 | 11.97 | 21.15 | 33.84 | 31.28 | 5.7 | 14.8 | 1.8 |
| 0.60 | 11636. | 4.07 | 1.44 | 1.51 | 12.23 | 21.90 | 35.03 | 28.57 | 5.6 | 13.0 | 1.7 |
| 0.70 | 11110. | 4.05 | 1.60 | 1.66 | 11.93 | 21.16 | 33.86 | 22.53 | 5.6 | 10.6 | 1.6 |
| 0.80 | 8217. | 3.91 | 1.95 | 1.72 | 13.26 | 22.21 | 35.54 | 20.42 | 6.0 | 9.2 | 1.5 |
| 0.90 | 8532. | 3.93 | 1.62 | 1.75 | 13.64 | 23.00 | 36.80 | 19.57 | 5.9 | 8.5 | 1.4 |
| 1.00 | 6514. | 3.81 | 1.67 | 1.64 | 13.57 | 21.77 | 34.84 | 23.29 | 6.2 | 10.7 | 1.6 |
| 1.10 | 8073. | 3.91 | 1.63 | 1.67 | 13.25 | 22.12 | 35.39 | 22.16 | 6.0 | 10.0 | 1.5 |
| 1.20 | 8186. | 3.91 | 1.71 | 1.81 | 13.31 | 22.27 | 35.63 | 17.63 | 6.0 | 7.9 | 1.4 |
| 1.30 | 10290. | 4.01 | 2.08 | 1.86 | 13.12 | 22.93 | 36.69 | 16.13 | 5.7 | 7.0 | 1.3 |
| 1.40 | 10752. | 4.03 | 1.78 | 1.94 | 14.43 | 25.43 | 40.69 | 13.93 | 5.7 | 5.5 | 1.2 |
| 1.50 | 7844. | 3.89 | 1.95 | 1.76 | 16.18 | 26.85 | 42.97 | 19.11 | 6.0 | 7.1 | 1.3 |
| 1.60 | 10647. | 4.03 | 1.55 | 1.84 | 15.46 | 27.20 | 43.52 | 16.58 | 5.7 | 6.1 | 1.3 |
| 1.70 | 9634. | 3.98 | 2.02 | 1.66 | 16.04 | 27.69 | 44.30 | 22.44 | 5.8 | 8.1 | 1.4 |
| 1.80 | 11430. | 4.06 | 1.41 | 1.80 | 18.11 | 32.31 | 51.69 | 17.72 | 5.6 | 5.5 | 1.2 |
| 1.90 | 10921. | 4.04 | 1.98 | 1.63 | 16.13 | 28.53 | 45.64 | 23.80 | 5.7 | 8.3 | 1.4 |
| 2.00 | 9438. | 3.97 | 1.49 | 1.83 | 12.06 | 20.74 | 33.18 | 17.01 | 5.8 | 8.2 | 1.4 |
| 2.10 | 10611. | 4.03 | 2.01 | 1.69 | 14.69 | 29.35 | 46.95 | 21.38 | 5.7 | 7.3 | 1.4 |
| 2.20 | 10398. | 4.02 | 1.57 | 1.57 | 15.76 | 27.57 | 44.11 | 25.83 | 5.7 | 9.4 | 1.5 |
| WHTE SITE 8 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 1342. | 3.13 | 1.01 | 1.01 | 18.71 | 23.43 | 37.48 | 61.04 | 8.0 | 26.1 | 2.5 |
| 0.20 | 60258. | 4.78 | 1.22 | 1.23 | 8.83 | 23.52 | 37.63 | 43.88 | 3.8 | 18.7 | 2.0 |
| 0.30 | 50153. | 4.70 | 1.45 | 1.34 | 8.39 | 21.20 | 33.91 | 37.05 | 4.0 | 17.5 | 2.0 |
| 0.40 | 49424. | 4.69 | 1.35 | 1.43 | 8.86 | 22.28 | 35.64 | 32.15 | 4.0 | 14.4 | 1.8 |
| 0.50 | 58361. | 4.77 | 1.50 | 1.47 | 9.78 | 25.79 | 41.26 | 30.39 | 3.8 | 11.8 | 1.6 |
| 0.60 | 36068. | 4.56 | 1.56 | 1.51 | 10.52 | 24.31 | 38.90 | 28.69 | 4.3 | 11.8 | 1.6 |
| 0.70 | 9288. | 3.97 | 1.46 | 1.54 | 14.31 | 24.53 | 39.25 | 27.07 | 5.8 | 11.0 | 1.6 |
| 0.80 | 7997. | 3.90 | 1.61 | 1.56 | 15.68 | 26.13 | 41.80 | 24.34 | 6.0 | 10.1 | 1.5 |
| 0.90 | 10273. | 4.01 | 1.61 | 1.63 | 20.58 | 35.95 | 57.52 | 23.47 | 5.7 | 6.5 | 1.3 |
| 1.00 | 9274. | 3.97 | 1.68 | 1.50 | 20.94 | 35.88 | 57.41 | 28.78 | 5.8 | 8.0 | 1.4 |
| 1.05 | 9675. | 3.99 | 1.22 | 1.22 | 21.20 | 36.61 | 58.57 | 44.25 | 5.8 | 12.1 | 1.6 |
| WHTE SITE 9 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 1368. | 3.14 | 1.27 | 1.27 | 13.00 | 16.32 | 26.11 | 41.17 | 8.0 | 25.2 | 2.4 |
| 0.20 | 14335. | 4.16 | 1.36 | 1.37 | 9.64 | 18.00 | 28.81 | 35.38 | 5.4 | 19.7 | 2.1 |
| 0.30 | 24217. | 4.38 | 1.47 | 1.51 | 14.49 | 30.38 | 48.61 | 28.38 | 4.8 | 9.3 | 1.5 |
| 0.40 | 26510. | 4.42 | 1.70 | 1.57 | 15.98 | 34.22 | 54.74 | 25.91 | 4.7 | 7.6 | 1.4 |
| 0.50 | 24385. | 4.39 | 1.54 | 1.63 | 14.66 | 30.78 | 49.25 | 23.63 | 4.8 | 7.7 | 1.4 |
| 0.60 | 28310. | 4.45 | 1.65 | 1.64 | 13.88 | 30.20 | 48.32 | 23.19 | 4.6 | 7.7 | 1.4 |
| 0.70 | 21477. | 4.33 | 1.74 | 1.72 | 13.00 | 24.52 | 42.43 | 20.48 | 4.9 | 7.7 | 1.4 |
| 0.80 | 17858. | 4.25 | 1.77 | 1.72 | 12.29 | 24.05 | 38.48 | 20.38 | 5.1 | 8.5 | 1.4 |
| 0.90 | 27518. | 4.44 | 1.66 | 1.74 | 11.81 | 25.52 | 40.84 | 19.82 | 4.6 | 7.8 | 1.4 |
| 1.00 | 29883. | 4.48 | 1.79 | 1.75 | 11.51 | 25.37 | 40.59 | 19.33 | 4.5 | 7.6 | 1.4 |
| 1.10 | 17247. | 4.24 | 1.81 | 1.63 | 11.47 | 22.27 | 35.64 | 23.50 | 5.1 | 10.5 | 1.5 |
| 1.20 | 23868. | 4.38 | 1.30 | 1.75 | 11.42 | 23.87 | 38.19 | 19.56 | 4.8 | 8.2 | 1.4 |
| 1.30 | 26536. | 4.42 | 2.12 | 1.70 | 11.12 | 23.83 | 38.13 | 21.19 | 4.7 | 8.9 | 1.4 |
| 1.40 | 22786. | 4.36 | 1.67 | 1.85 | 11.37 | 23.51 | 37.62 | 16.41 | 4.8 | 7.0 | 1.3 |
| 1.50 | 31629. | 4.50 | 1.74 | 1.67 | 10.03 | 22.41 | 35.86 | 22.24 | 4.5 | 9.9 | 1.5 |
| 1.60 | 31256. | 4.49 | 1.59 | 1.52 | 10.05 | 22.40 | 35.84 | 23.94 | 4.5 | 10.7 | 1.6 |
| 1.70 | 37427. | 4.57 | 1.54 | 1.32 | 10.28 | 23.99 | 38.39 | 38.69 | 4.3 | 15.9 | 1.9 |
| 1.80 | 25292. | 4.40 | 0.84 | 1.31 | 10.86 | 22.99 | 36.79 | 38.55 | 4.7 | 16.8 | 1.9 |
| 1.90 | 31836. | 4.50 | 1.56 | 1.29 | 10.18 | 22.75 | 36.41 | 39.64 | 4.5 | 17.4 | 2.0 |
| 2.00 | 32885. | 4.52 | 1.48 | 1.53 | 9.40 | 21.22 | 33.95 | 27.46 | 4.4 | 12.9 | 1.7 |
| 2.10 | 29546. | 4.47 | 1.56 | 1.49 | 8.50 | 18.70 | 29.92 | 29.27 | 4.5 | 15.7 | 1.9 |
| 2.20 | 26399. | 4.42 | 1.44 | 1.69 | 7.93 | 16.97 | 27.15 | 21.33 | 4.7 | 12.6 | 1.7 |
| 2.25 | 29808. | 4.47 | 2.08 | 2.08 | 9.62 | 21.20 | 33.92 | 10.30 | 4.5 | 4.9 | 1.2 |

Table 22.--Data for defining moisture relations in soils--Continued

| N | DEPTH | RETENTION FORCE | | VOLUME WEIGHT | AVERAGE VOLUME WEIGHT | SOIL MOISTURE | MOISTURE RETENTION CAPABILITY | ADSORPTION CAPACITY | VOID MOISTURE CAPACITY | SOIL MOISTURE | VOID MOISTURE CAPACITY | PERMEABILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | B/30CM | PF | G/CC | G/CC | % | % | % | % | MOLECULAR LAYERS OF WATER | MOLECULAR LAYERS OF WATER | CM/HR |
| WHTE SITE 10 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | | |
| | 0.10 | 321. | 2.51 | 1.02 | 1.02 | 16.10 | 16.89 | 27.03 | 68.47 | 9.6 | 35.8 | 3.1 |
| | 0.20 | 22105. | 4.34 | 1.40 | 1.24 | 11.15 | 22.88 | 36.61 | 42.72 | 4.9 | 18.7 | 2.8 |
| | 0.30 | 24925. | 4.40 | 1.31 | 1.34 | 10.94 | 23.10 | 36.96 | 36.78 | 4.7 | 15.9 | 1.9 |
| | 0.40 | 16490. | 4.22 | 1.32 | 1.33 | 8.85 | 17.03 | 27.24 | 37.53 | 5.2 | 22.0 | 2.2 |
| | 0.50 | 18070. | 4.26 | 1.36 | 1.36 | 9.02 | 17.69 | 28.31 | 35.86 | 5.1 | 20.3 | 2.1 |
| | 0.60 | 20375. | 4.31 | 1.40 | 1.40 | 8.40 | 16.92 | 27.08 | 33.58 | 5.0 | 19.8 | 2.1 |
| | 0.70 | 12336. | 4.09 | 1.45 | 1.59 | 5.29 | 9.58 | 15.33 | 25.20 | 5.5 | 26.3 | 2.5 |
| | 0.80 | 10421. | 4.22 | 1.92 | 1.79 | 3.23 | 6.22 | 9.94 | 18.24 | 5.2 | 29.4 | 2.7 |
| | 0.90 | 1429R. | 4.16 | 1.99 | 2.09 | 3.62 | 6.76 | 10.81 | 10.13 | 5.4 | 15.0 | 1.8 |
| | 1.00 | 5681. | 3.75 | 2.36 | 1.97 | 3.90 | 6.10 | 9.77 | 12.92 | 4.4 | 21.2 | 2.2 |
| | 1.10 | 512R. | 3.71 | 1.58 | 1.91 | 4.10 | 6.31 | 10.09 | 14.54 | 5.5 | 23.1 | 2.3 |
| | 1.20 | 6689. | 3.83 | 1.81 | 1.87 | 4.42 | 7.13 | 11.41 | 15.83 | 6.2 | 22.2 | 2.3 |
| | 1.30 | 747R. | 3.87 | 2.22 | 2.05 | 4.23 | 6.95 | 11.13 | 11.03 | 6.1 | 15.9 | 1.9 |
| | 1.40 | 976R. | 3.99 | 2.13 | 1.86 | 4.43 | 7.66 | 12.26 | 15.98 | 5.8 | 20.9 | 2.2 |
| | 1.50 | 1042R. | 4.02 | 1.24 | 1.62 | 10.78 | 18.90 | 30.23 | 23.82 | 5.7 | 12.6 | 1.7 |
| | 1.60 | 9600. | 3.98 | 1.51 | 1.61 | 8.74 | 15.68 | 24.12 | 24.27 | 5.8 | 16.1 | 1.9 |
| | 1.70 | 12911. | 4.11 | 2.09 | 1.67 | 9.50 | 17.37 | 27.80 | 22.27 | 5.5 | 12.8 | 1.7 |
| | 1.80 | 1800R. | 4.26 | 1.40 | 1.84 | 9.16 | 17.96 | 28.74 | 16.65 | 5.1 | 9.3 | 1.5 |
| | 1.90 | 11059. | 4.04 | 2.02 | 1.61 | 5.44 | 9.64 | 15.42 | 24.46 | 5.6 | 25.4 | 2.4 |
| | 2.00 | 15170. | 4.18 | 1.40 | 1.77 | 3.56 | 6.73 | 10.77 | 18.92 | 5.3 | 28.1 | 2.6 |
| | 2.10 | 1029R. | 4.21 | 1.87 | 1.65 | 11.99 | 23.00 | 36.61 | 23.08 | 5.2 | 10.0 | 1.5 |
| | 2.20 | 8701. | 3.94 | 1.67 | 1.83 | 18.19 | 30.79 | 49.26 | 16.67 | 5.9 | 5.5 | 1.2 |
| | 2.30 | 9951. | 4.00 | 1.95 | 1.67 | 18.34 | 31.84 | 50.95 | 22.11 | 5.8 | 6.9 | 1.3 |
| | 2.40 | 12861. | 4.11 | 1.39 | 1.39 | 15.67 | 28.62 | 45.80 | 34.12 | 5.5 | 11.9 | 1.6 |
| WHTE SITE 11 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | | |
| | 0.10 | 3785. | 3.58 | 1.23 | 1.23 | 10.86 | 15.89 | 25.43 | 43.88 | 6.8 | 27.6 | 2.6 |
| | 0.20 | 17370. | 4.24 | 1.13 | 1.29 | 10.10 | 19.64 | 31.43 | 40.04 | 5.1 | 20.4 | 2.1 |
| | 0.30 | 20088. | 4.30 | 1.50 | 1.34 | 9.92 | 19.92 | 31.88 | 36.80 | 5.0 | 18.5 | 2.0 |
| | 0.40 | 11565. | 4.06 | 1.39 | 1.50 | 11.00 | 19.68 | 31.49 | 28.88 | 5.6 | 14.7 | 1.8 |
| | 0.50 | 11801. | 4.07 | 1.61 | 1.54 | 10.83 | 19.45 | 31.13 | 27.49 | 5.6 | 14.1 | 1.8 |
| | 0.60 | 9537. | 3.98 | 1.60 | 1.60 | 12.15 | 20.92 | 33.47 | 24.80 | 5.8 | 11.9 | 1.6 |
| | 0.70 | 4850. | 3.69 | 1.59 | 1.57 | 13.72 | 20.92 | 33.47 | 25.81 | 6.6 | 12.3 | 1.7 |
| | 0.80 | 8250. | 3.92 | 1.53 | 1.58 | 11.80 | 19.76 | 31.62 | 25.38 | 6.0 | 12.8 | 1.7 |
| | 0.90 | 6140. | 3.79 | 1.64 | 1.60 | 14.59 | 23.17 | 37.08 | 24.76 | 6.3 | 10.7 | 1.6 |
| | 1.00 | 4839. | 3.68 | 1.63 | 1.64 | 15.08 | 22.98 | 36.76 | 23.26 | 6.6 | 10.1 | 1.5 |
| | 1.10 | 6114. | 3.79 | 1.65 | 1.74 | 14.72 | 23.36 | 37.38 | 19.44 | 6.3 | 8.4 | 1.4 |
| | 1.20 | 6633. | 3.82 | 1.95 | 1.84 | 12.87 | 20.72 | 33.16 | 16.73 | 6.2 | 8.1 | 1.4 |
| | 1.30 | 6017. | 3.78 | 1.91 | 1.93 | 13.54 | 21.43 | 34.29 | 14.10 | 6.3 | 6.6 | 1.3 |
| | 1.40 | 7192. | 3.86 | 1.93 | 1.93 | 14.69 | 24.00 | 38.41 | 14.15 | 6.1 | 5.9 | 1.3 |
| WHTE SITE 13 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | | |
| | 0.10 | 888. | 2.95 | 0.96 | 0.96 | 20.42 | 24.17 | 38.67 | 66.00 | 8.4 | 27.3 | 2.6 |
| | 0.20 | 11315. | 4.05 | 1.25 | 1.14 | 9.23 | 16.44 | 26.30 | 50.15 | 5.6 | 30.5 | 2.8 |
| | 0.30 | 21274. | 4.33 | 1.20 | 1.30 | 9.38 | 19.09 | 30.55 | 39.14 | 4.9 | 20.5 | 2.2 |
| | 0.40 | 23844. | 4.38 | 1.45 | 1.39 | 8.93 | 18.66 | 29.85 | 34.08 | 4.8 | 18.3 | 2.0 |
| | 0.50 | 14589. | 4.16 | 1.52 | 1.48 | 9.93 | 18.62 | 29.78 | 29.84 | 5.3 | 16.0 | 1.9 |
| | 0.60 | 17007. | 4.23 | 1.47 | 1.52 | 11.20 | 21.70 | 34.72 | 27.85 | 5.2 | 12.8 | 1.7 |
| | 0.70 | 23678. | 4.37 | 1.59 | 1.54 | 10.07 | 21.00 | 33.60 | 27.14 | 4.8 | 12.9 | 1.7 |
| | 0.80 | 15282. | 4.18 | 1.57 | 1.52 | 10.11 | 19.15 | 30.63 | 28.01 | 5.3 | 14.6 | 1.8 |
| | 0.90 | 18504. | 4.27 | 1.41 | 1.52 | 11.45 | 22.58 | 36.13 | 28.03 | 5.1 | 12.4 | 1.7 |
| | 1.00 | 22813. | 4.36 | 1.59 | 1.49 | 9.33 | 19.29 | 30.87 | 29.44 | 4.8 | 15.3 | 1.8 |
| | 1.10 | 17831. | 4.25 | 1.48 | 1.52 | 8.43 | 16.49 | 26.39 | 27.85 | 5.1 | 16.9 | 1.9 |
| | 1.20 | 31794. | 4.50 | 1.51 | 1.63 | 7.27 | 16.28 | 26.04 | 23.69 | 4.5 | 14.6 | 1.8 |
| | 1.30 | 33234. | 4.52 | 1.90 | 1.67 | 6.74 | 15.26 | 24.41 | 22.15 | 4.4 | 14.5 | 1.8 |
| | 1.40 | 28557. | 4.46 | 1.69 | 1.82 | 6.97 | 15.19 | 24.30 | 17.24 | 4.6 | 11.4 | 1.6 |
| | 1.50 | 29995. | 4.48 | 1.96 | 1.58 | 7.62 | 16.82 | 26.92 | 25.43 | 4.5 | 15.1 | 1.8 |
| | 1.60 | 35998. | 4.56 | 1.19 | 1.72 | 8.14 | 18.80 | 30.07 | 20.38 | 4.3 | 10.9 | 1.6 |
| | 1.70 | 24633. | 4.39 | 2.01 | 1.55 | 7.20 | 15.16 | 24.26 | 26.59 | 4.8 | 17.5 | 2.0 |
| | 1.80 | 25264. | 4.40 | 1.46 | 1.63 | 6.45 | 13.65 | 21.84 | 23.77 | 4.7 | 17.4 | 2.0 |
| | 1.90 | 31029. | 4.49 | 1.40 | 1.41 | 6.68 | 14.87 | 23.79 | 32.95 | 4.5 | 22.2 | 2.3 |
| | 2.00 | 21817. | 4.34 | 1.38 | 1.54 | 6.72 | 13.76 | 22.01 | 25.61 | 4.9 | 18.6 | 2.0 |
| | 2.10 | 19778. | 4.30 | 1.95 | 1.58 | 7.15 | 14.31 | 22.89 | 25.44 | 5.0 | 17.8 | 2.0 |
| | 2.20 | 26719. | 4.43 | 1.41 | 1.75 | 7.29 | 15.65 | 25.04 | 19.55 | 4.7 | 12.5 | 1.7 |
| | 2.30 | 18824. | 4.27 | 1.87 | 1.48 | 7.65 | 15.16 | 24.25 | 29.65 | 5.1 | 19.6 | 2.1 |
| | 2.40 | 22162. | 4.35 | 1.17 | 1.17 | 7.81 | 16.04 | 25.66 | 47.83 | 4.9 | 29.8 | 2.7 |

Table 22.--Data for defining moisture relations in soils--Continued

| M DEPTH | RETENTION FORCE | VOLUME WEIGHT | AVERAGE VOLUME WEIGHT | SOIL MOISTURE | MOISTURE RETENTION CAPABILITY | ADSORPTION CAPACITY | VOID MOISTURE CAPACITY | SOIL MOISTURE | VOID MOISTURE CAPACITY | PERMEABILITY |
|---|---|---|---|---|---|---|---|---|---|---|
| M | G/SQCM PF | G/CC | G/CC | % | % | % | % | MOLECULAR LAYERS OF WATER | MOLECULAR LAYERS OF WATER | CM/HR |
| WHTE SITE 12 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | |
| 0.10 | 592. 2.77 | 0.96 | 0.96 | 14.33 | 16.10 | 25.76 | 64.75 | 8.9 | 41.5 | 3.4 |
| 0.20 | 19628. 4.29 | 1.26 | 1.24 | 7.23 | 14.45 | 23.12 | 43.01 | 5.0 | 29.8 | 2.7 |
| 0.30 | 27898. 4.45 | 1.50 | 1.27 | 8.44 | 18.29 | 29.27 | 40.72 | 4.6 | 22.3 | 2.3 |
| 0.40 | 14588. 4.16 | 1.07 | 1.23 | 8.66 | 16.23 | 25.97 | 43.29 | 5.3 | 26.7 | 2.5 |
| 0.50 | 18115. 4.26 | 1.13 | 1.11 | 8.57 | 16.83 | 26.92 | 52.27 | 5.1 | 31.1 | 2.8 |
| 0.60 | 16968. 4.23 | 1.13 | 1.25 | 8.79 | 17.02 | 27.24 | 42.09 | 5.2 | 24.7 | 2.4 |
| 0.70 | 10088. 4.00 | 1.49 | 1.29 | 8.84 | 15.38 | 24.61 | 39.80 | 5.7 | 25.9 | 2.5 |
| 0.80 | 10783. 4.03 | 1.25 | 1.41 | 9.03 | 15.93 | 25.49 | 33.33 | 5.7 | 20.9 | 2.2 |
| 0.90 | 12124. 4.08 | 1.49 | 1.31 | 9.00 | 16.25 | 26.00 | 38.86 | 5.5 | 23.9 | 2.4 |
| 1.00 | 8923. 3.95 | 1.19 | 1.41 | 9.15 | 15.56 | 24.90 | 33.26 | 5.9 | 21.4 | 2.2 |
| 1.10 | 12458. 4.10 | 1.55 | 1.40 | 8.57 | 15.56 | 24.89 | 33.63 | 5.5 | 21.6 | 2.2 |
| 1.20 | 14198. 4.15 | 1.46 | 1.43 | 8.43 | 15.71 | 25.13 | 32.35 | 5.4 | 20.6 | 2.2 |
| 1.30 | 11042. 4.04 | 1.26 | 1.38 | 8.52 | 15.09 | 24.14 | 35.78 | 5.6 | 23.7 | 2.3 |
| 1.40 | 11068. 4.04 | 1.35 | 1.14 | 8.60 | 15.24 | 24.39 | 49.90 | 5.6 | 32.7 | 2.9 |
| 1.50 | 10683. 4.27 | 0.81 | 0.81 | 9.24 | 18.27 | 29.23 | 86.31 | 5.1 | 47.2 | 3.0 |
| WHTE SITE 14 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | |
| 0.10 | 2330. 3.37 | 1.18 | 1.18 | 11.52 | 15.63 | 25.00 | 46.90 | 7.4 | 30.0 | 2.7 |
| 0.20 | 10801. 4.03 | 1.12 | 1.26 | 8.26 | 14.57 | 23.31 | 41.65 | 5.7 | 28.6 | 2.6 |
| 0.30 | 14984. 4.18 | 1.48 | 1.32 | 8.50 | 16.03 | 25.64 | 37.93 | 5.3 | 23.7 | 2.3 |
| 0.40 | 17149. 4.23 | 1.37 | 1.43 | 8.87 | 17.22 | 27.55 | 32.39 | 5.2 | 18.8 | 2.0 |
| 0.50 | 13364. 4.13 | 1.43 | 1.38 | 8.24 | 15.18 | 24.29 | 34.93 | 5.4 | 23.0 | 2.3 |
| 0.60 | 12737. 4.11 | 1.33 | 1.48 | 7.23 | 13.18 | 21.09 | 29.61 | 5.5 | 22.5 | 2.3 |
| 0.70 | 12717. 4.10 | 1.49 | 1.43 | 7.63 | 13.91 | 22.26 | 32.02 | 5.5 | 23.0 | 2.3 |
| 0.80 | 9315. 3.97 | 1.28 | 1.61 | 8.93 | 15.30 | 24.49 | 24.28 | 5.8 | 15.9 | 1.9 |
| 0.90 | 11363. 4.06 | 1.87 | 1.65 | 8.67 | 15.45 | 24.71 | 23.01 | 5.6 | 14.9 | 1.8 |
| 1.00 | 14077. 4.15 | 1.79 | 1.66 | 8.49 | 15.81 | 25.29 | 22.34 | 5.4 | 14.1 | 1.8 |
| 1.10 | 10864. 4.04 | 1.33 | 1.67 | 8.33 | 14.72 | 23.55 | 22.11 | 5.7 | 15.0 | 1.8 |
| 1.20 | 11142. 4.05 | 1.89 | 1.67 | 9.47 | 16.81 | 26.89 | 21.98 | 5.6 | 13.1 | 1.7 |
| 1.30 | 11525. 4.06 | 1.81 | 1.79 | 10.46 | 18.70 | 29.92 | 18.19 | 5.6 | 9.7 | 1.5 |
| 1.40 | 8739. 3.94 | 1.67 | 1.84 | 14.31 | 24.23 | 38.77 | 16.76 | 5.9 | 6.9 | 1.3 |
| 1.50 | 10079. 4.00 | 2.03 | 1.82 | 15.55 | 27.07 | 43.31 | 17.18 | 5.7 | 6.3 | 1.3 |
| 1.60 | 11834. 4.07 | 1.76 | 1.99 | 15.56 | 27.95 | 44.72 | 12.43 | 5.6 | 4.5 | 1.2 |
| 1.70 | 8744. 3.94 | 2.17 | 1.95 | 15.28 | 25.89 | 41.43 | 13.60 | 5.9 | 5.3 | 1.2 |
| 1.80 | 8545. 3.93 | 1.92 | 1.98 | 14.35 | 24.20 | 38.72 | 12.67 | 5.9 | 5.2 | 1.2 |
| 1.90 | 9218. 3.96 | 1.87 | 1.86 | 15.93 | 27.25 | 43.61 | 16.17 | 5.8 | 5.9 | 1.3 |
| 2.00 | 7418. 3.87 | 1.78 | 1.88 | 16.27 | 26.74 | 42.78 | 15.57 | 6.1 | 5.8 | 1.3 |
| 2.10 | 8930. 3.95 | 1.98 | 1.92 | 17.51 | 29.77 | 47.64 | 14.43 | 5.9 | 4.8 | 1.2 |
| 2.20 | 9017. 3.96 | 1.99 | 1.99 | 17.45 | 29.73 | 47.56 | 12.43 | 5.9 | 4.2 | 1.2 |
| WHTE SITE 15 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | |
| 0.10 | 12208. 4.09 | 0.94 | 0.94 | 14.01 | 25.32 | 40.51 | 69.08 | 5.5 | 27.3 | 2.6 |
| 0.20 | 26092. 4.42 | 1.05 | 1.11 | 10.59 | 22.59 | 36.14 | 52.53 | 4.7 | 23.3 | 2.3 |
| 0.30 | 26628. 4.43 | 1.33 | 1.27 | 11.43 | 24.51 | 39.22 | 41.23 | 4.7 | 16.8 | 1.9 |
| 0.40 | 17045. 4.23 | 1.41 | 1.47 | 10.83 | 20.98 | 33.57 | 30.45 | 5.2 | 14.5 | 1.8 |
| 0.50 | 20552. 4.31 | 1.65 | 1.54 | 10.92 | 22.05 | 35.28 | 27.36 | 5.0 | 12.4 | 1.7 |
| 0.60 | 21297. 4.33 | 1.54 | 1.56 | 11.68 | 23.37 | 37.39 | 26.44 | 4.9 | 11.3 | 1.6 |
| 0.70 | 14557. 4.16 | 1.48 | 1.51 | 11.32 | 21.21 | 33.93 | 28.59 | 5.3 | 13.5 | 1.7 |
| 0.80 | 14064. 4.15 | 1.50 | 1.44 | 11.76 | 21.88 | 35.00 | 31.61 | 5.4 | 14.4 | 1.8 |
| 0.90 | 16403. 4.21 | 1.35 | 1.41 | 12.10 | 23.25 | 37.20 | 33.18 | 5.2 | 14.3 | 1.8 |
| 1.00 | 9246. 3.97 | 1.38 | 1.42 | 12.92 | 22.12 | 35.39 | 32.90 | 5.8 | 14.9 | 1.8 |
| 1.10 | 11620. 4.07 | 1.52 | 1.39 | 12.24 | 21.92 | 35.07 | 34.25 | 5.6 | 15.6 | 1.9 |
| 1.20 | 14321. 4.16 | 1.27 | 1.53 | 12.51 | 23.36 | 37.38 | 27.74 | 5.4 | 11.9 | 1.6 |
| 1.30 | 8436. 3.94 | 1.80 | 1.49 | 11.64 | 19.68 | 31.48 | 29.45 | 5.9 | 15.0 | 1.8 |
| 1.40 | 12838. 4.11 | 1.40 | 1.63 | 11.57 | 21.13 | 33.81 | 23.44 | 5.5 | 11.1 | 1.6 |
| 1.50 | 12483. 4.10 | 1.71 | 1.51 | 9.35 | 16.97 | 27.15 | 28.40 | 5.5 | 16.7 | 1.9 |
| 1.60 | 18107. 4.26 | 1.43 | 1.69 | 10.19 | 20.00 | 32.00 | 24.81 | 5.1 | 12.4 | 1.7 |
| 1.70 | 7824. 3.89 | 1.66 | 1.50 | 9.61 | 15.95 | 25.52 | 29.80 | 6.0 | 18.2 | 2.0 |
| 1.80 | 8063. 3.91 | 1.40 | 1.58 | 12.33 | 20.58 | 32.93 | 25.40 | 6.0 | 12.3 | 1.7 |
| 1.90 | 6053. 3.78 | 1.68 | 1.66 | 12.06 | 19.11 | 30.58 | 22.50 | 6.3 | 11.8 | 1.6 |
| 2.00 | 8574. 3.93 | 1.89 | 1.59 | 12.15 | 20.51 | 32.82 | 25.34 | 5.9 | 12.4 | 1.7 |
| 2.10 | 8063. 3.91 | 1.18 | 1.53 | 13.17 | 21.98 | 35.17 | 27.80 | 6.0 | 12.6 | 1.7 |
| 2.20 | 6141. 3.79 | 1.51 | 1.32 | 13.56 | 21.54 | 34.46 | 38.30 | 6.3 | 17.8 | 2.0 |
| 2.30 | 6800. 3.83 | 1.26 | 1.20 | 15.31 | 24.76 | 39.62 | 45.84 | 6.2 | 18.5 | 2.0 |
| 2.40 | 5618. 3.75 | 0.92 | 1.00 | 16.78 | 26.23 | 41.97 | 62.57 | 6.4 | 23.9 | 2.4 |
| 2.50 | 3599. 3.56 | 0.91 | 0.92 | 15.61 | 22.65 | 36.24 | 70.77 | 6.9 | 31.3 | 2.8 |
| 2.60 | 3534. 3.55 | 1.03 | 0.91 | 17.65 | 25.54 | 40.87 | 72.18 | 6.9 | 28.3 | 2.6 |
| 2.70 | 5023. 3.70 | 0.79 | 1.08 | 16.41 | 25.16 | 40.26 | 54.93 | 6.5 | 21.9 | 2.2 |
| 2.80 | 2757. 3.44 | 1.42 | 1.21 | 17.99 | 25.02 | 40.04 | 44.65 | 7.2 | 17.9 | 2.0 |
| 2.90 | 2918. 3.47 | 1.43 | 1.46 | 19.16 | 26.89 | 43.03 | 30.69 | 7.1 | 11.4 | 1.6 |
| 3.00 | 1931. 3.29 | 1.55 | 1.55 | 18.32 | 24.16 | 38.66 | 28.98 | 7.6 | 11.2 | 1.6 |

Table 22.--Data for defining moisture relations in soils--Continued

| M DEPTH | RETENTION FORCE | | VOLUME WEIGHT | AVERAGE VOLUME WEIGHT | SOIL MOISTURE | MOISTURE RETENTION CAPABILITY | ADSORPTION CAPACITY | VOID MOISTURE CAPACITY | SOIL MOISTURE | VOID MOISTURE CAPACITY | PERMEABILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M | G/SQCM | PF | G/CC | G/CC | % | % | % | % | MOLECULAR LAYERS OF WATER | MOLECULAR LAYERS OF WATER | CM/HR |
| WHTE SITE 16 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 3819. | 3.58 | 1.10 | 1.10 | 11.88 | 17.40 | 27.85 | 53.12 | 6.8 | 30.5 | 2.8 |
| 0.20 | 8708. | 3.94 | 1.39 | 1.25 | 14.68 | 24.85 | 39.76 | 42.02 | 5.9 | 16.9 | 1.9 |
| 0.30 | 8023. | 3.90 | 1.27 | 1.34 | 13.84 | 23.06 | 36.90 | 36.94 | 6.0 | 16.0 | 1.9 |
| 0.40 | 5398. | 3.73 | 1.36 | 1.36 | 12.26 | 19.04 | 30.47 | 35.79 | 6.6 | 18.8 | 2.0 |
| 0.50 | 5107. | 3.71 | 1.45 | 1.42 | 11.90 | 18.31 | 29.29 | 32.63 | 6.5 | 17.8 | 2.0 |
| 0.60 | 4171. | 3.62 | 1.45 | 1.41 | 13.48 | 20.04 | 32.07 | 33.34 | 6.7 | 16.6 | 1.9 |
| 0.70 | 2542. | 3.41 | 1.31 | 1.35 | 14.69 | 20.18 | 32.29 | 36.18 | 7.3 | 17.9 | 2.0 |
| 0.80 | 2240. | 3.35 | 1.29 | 1.29 | 15.84 | 21.35 | 34.16 | 39.63 | 7.4 | 18.6 | 2.0 |
| WHTE SITE 17 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 4718. | 3.67 | 1.19 | 1.19 | 10.01 | 15.19 | 24.30 | 46.09 | 6.6 | 30.3 | 2.7 |
| 0.20 | 26281. | 4.42 | 1.33 | 1.28 | 11.83 | 25.28 | 40.45 | 40.25 | 4.7 | 15.9 | 1.9 |
| 0.30 | 28202. | 4.45 | 1.32 | 1.35 | 12.64 | 27.47 | 43.95 | 35.18 | 4.6 | 13.2 | 1.7 |
| 0.40 | 34490. | 4.54 | 1.40 | 1.43 | 11.84 | 27.05 | 43.28 | 32.19 | 4.4 | 11.9 | 1.6 |
| 0.50 | 23529. | 4.37 | 1.57 | 1.48 | 10.46 | 21.78 | 34.85 | 29.83 | 4.8 | 13.7 | 1.7 |
| 0.60 | 22791. | 4.36 | 1.47 | 1.51 | 9.67 | 19.99 | 31.98 | 28.47 | 4.8 | 14.3 | 1.8 |
| 0.70 | 19498. | 4.29 | 1.48 | 1.47 | 10.15 | 20.26 | 32.42 | 30.35 | 5.0 | 15.0 | 1.8 |
| 0.80 | 15830. | 4.20 | 1.45 | 1.47 | 17.06 | 32.53 | 52.05 | 30.22 | 5.2 | 9.3 | 1.5 |
| 0.90 | 21644. | 4.34 | 1.48 | 1.54 | 9.12 | 18.62 | 29.80 | 27.25 | 4.9 | 14.6 | 1.8 |
| 1.00 | 30599. | 4.49 | 1.68 | 1.54 | 9.41 | 20.86 | 33.37 | 27.18 | 4.5 | 13.0 | 1.7 |
| 1.10 | 18640. | 4.27 | 1.46 | 1.55 | 10.51 | 20.77 | 33.23 | 26.83 | 5.1 | 12.9 | 1.7 |
| 1.20 | 21548. | 4.33 | 1.50 | 1.49 | 10.86 | 22.17 | 35.47 | 29.17 | 4.9 | 13.2 | 1.7 |
| 1.30 | 23055. | 4.36 | 1.52 | 1.49 | 11.26 | 23.33 | 37.33 | 29.27 | 4.8 | 12.5 | 1.7 |
| 1.40 | 23868. | 4.41 | 1.45 | 1.50 | 10.90 | 23.20 | 37.12 | 29.14 | 4.7 | 12.6 | 1.7 |
| 1.50 | 19949. | 4.30 | 1.51 | 1.35 | 10.41 | 20.88 | 33.41 | 36.16 | 5.0 | 17.3 | 2.0 |
| 1.60 | 22065. | 4.34 | 1.09 | 1.42 | 9.69 | 19.88 | 31.81 | 32.51 | 4.9 | 16.4 | 1.9 |
| 1.70 | 20349. | 4.31 | 1.66 | 1.33 | 10.14 | 20.42 | 32.68 | 37.22 | 5.0 | 18.2 | 2.0 |
| 1.80 | 20052. | 4.30 | 1.24 | 1.51 | 10.12 | 20.32 | 32.51 | 28.66 | 5.0 | 14.1 | 1.8 |
| 1.90 | 13469. | 4.13 | 1.61 | 1.45 | 11.24 | 20.73 | 33.17 | 31.06 | 5.4 | 15.0 | 1.8 |
| 2.00 | 15713. | 4.20 | 1.51 | 1.54 | 11.03 | 21.01 | 33.62 | 27.31 | 5.3 | 13.0 | 1.7 |
| 2.10 | 16372. | 4.21 | 1.49 | 1.44 | 10.83 | 20.80 | 33.27 | 31.95 | 5.2 | 15.4 | 1.8 |
| 2.20 | 13452. | 4.13 | 1.30 | 1.37 | 10.33 | 19.05 | 30.48 | 35.47 | 5.4 | 18.6 | 2.0 |
| 2.30 | 12321. | 4.09 | 1.30 | 1.35 | 9.94 | 18.01 | 28.81 | 36.30 | 5.5 | 20.2 | 2.1 |
| 2.40 | 13869. | 4.14 | 1.45 | 1.45 | 10.45 | 19.39 | 31.03 | 31.28 | 5.4 | 16.1 | 1.9 |
| WHTE SITE 18 DATE: 9/25/76 SAMPLE NO. 1 VEGETATION TYPE: | | | | | | | | | | | |
| 0.10 | 1538. | 3.19 | 0.71 | 0.71 | 15.29 | 19.52 | 31.23 | 102.53 | 7.8 | 52.5 | 4.1 |
| 0.20 | 16187. | 4.21 | 1.40 | 1.13 | 7.06 | 13.54 | 21.66 | 50.59 | 5.2 | 37.4 | 3.2 |
| 0.30 | 25359. | 4.40 | 1.28 | 1.28 | 7.94 | 16.82 | 26.92 | 40.38 | 4.7 | 24.0 | 2.4 |

# SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
William B. Peters, Luvern L. Resler, and Robert Vader 1/

Soil is characterized by laboratory methods to confirm judgment in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is

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to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio [Richards, 1954].

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase I of the scheme, all samples would be characterized for (1) soil structure stability through measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, <u>selected</u> samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, <u>selected</u> samples suspected through the testing results of Phases I and II to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase I to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases I, II, and IV to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

Exhibit 2
(Includes the following 16 pages)

SUPPORTING DATA

Soil Profile Descriptions (BLM 7310-9) Followed by Determination of Erosion Condition Class (BLM 7310-12) for the Following Point Site Profiles in the Order Listed:

Profile No. 25 - Sec. 30, T. 56 N., R. 72 W.
Profile No. 29 - Sec. 25, T. 56 N., R. 73 W.
Profile No. 26 - Sec. 30, T. 56 N., R. 72 W.
Profile No. 14 - Sec. 31, T. 56 N., R. 72 W.
Profile No. 13 - Sec. 31, T. 56 N., R. 72 W.
Profile No. 15 - Sec. 31, T. 56 N., R. 72 W.
Profile No. 24 - Sec. 30, T. 56 N., R. 72 W.
Profile No. 28 - Sec. 25. T. 56 N., R. 73 W.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

**VEGETATION–SOIL DESCRIPTION**

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | 15 | Hamstone | 8035 | Fiecht! | 7 mo 76 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| — | LS | (25) Sec. 30, T. 56N, R. 72W | — | 25 | — | Sand shale |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Fort Union | Stone — Rock — | Alkaline Non – mod Saline Non – mod Water table None | Residual |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| 4-6% ☐ Single ☑ Complex | N | 4210 | Type Gully SSF 40 Class Sli. | B |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st, 2nd, 3rd, 4th | — Air — Soil | Days ——> 28° | Well drained | Mod. Slow - Moderate | Mod. Slow - Moderate | 10 in | 8.8" (4") in |

| 32. HORIZON | 33. THICKNESS | 34. COLOR DRY MOIST — MATRIX | 34. COLOR DRY MOIST — MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A2 | 0-1" | (D) 2.5Y 6/2 (M) 2.5Y 5/2 | | Sil | f1sbk/ m1cr | (D) so (M) lo | — | 2 | — | — | a |
| A3 | 1-2" | (D) 10YR 6/3 (M) 10YR 5/2 | | SiL | m2bk/ f2blk | (D) sh (M) fr | — | 2 | — | — | g |
| B2t | 2-7" | (D) 10YR 6/3 (M) 10YR 4/3 | | CL | m2pr/ m-f2bk | (D) sh (M) fr | lm | 2 | — | — | g |
| B3ca | 7-10" | (D) 10YR 7/3 (M) 10YR 5/3 | | CL | m2pr/ m2bk | (D) h (M) fr | — | 2 | — | ev | a |
| C1ca | 10-18" | (D) 10YR 6/3 (M) 10YR 5/3 | 10YR 8/1 10YR 8/2 | CL | c2bk/ m2bk | (D) h (M) fr | — | 1 | — | ev | g |
| C2ca | 18-30" | (D) 10YR 7/3 (M) 10YR 6/3 | 10YR 8/1 10YR 8/2 | SiCL | c1bk/ m1bk | (D) vh (M) fr | — | 1 | — | ev | a |
| C3ca | 30-54" | (D) 2.5Y 6/2 (M) 2.5Y 5/2 | 10YR 7/6 10YR 6/6 | SiCL | ssh | (D) vh (M) fi | — | | — | ev | a |
| C4ca | 54-78" | (D) 2.5Y 7/2 (M) 2.5Y 6/2 | 10YR 7/4 10YR 6/3 | SiCL | ssh | (D) vh (M) fi | — | | — | ev | a |
| R | 78"+ | Bedrock | | | | | | | | | |

10-30" many fine lime mottlings & lime accumulations

30"+ Sandy calcareous shale with mottling influence.

ssh = massive stratified sandy shales

(Instructions inside back cover)

Form 7310–9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By Frechtl | Date 7/76

Location Profile 25
Sec. 30, T. 56N, R. 72W

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT* | No visual evidence of movement<br>0 1 2 3 | Some movement of soil particles<br>4 5 | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 (7) 8 | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions<br>12 13 14 |
| SURFACE LITTER* | Accumulating in place<br>0 1 2 3 | May show slight movement<br>4 5 (6) | Moderate movement is apparent, deposited against obstacles<br>7 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>12 13 14 |
| SURFACE ROCK* | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 2 | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>3 4 (5) | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 7 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDES-TALLING* | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>4 5 (6) | Small rock and plant pedestals occurring in flow patterns<br>7 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 11 | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS* | No visual evidence of flow patterns<br>0 1 2 3 | Deposition of particles may be in evidence<br>4 5 (6) | Well defined, small, and few with intermittent deposits<br>7 8 9 | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 (3) | Some rills in evidence at infrequent intervals over 10'<br>4 5 6 | Rills ½" to 6" deep occur in exposed places at approximately 10' intervals<br>7 8 9 | Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>0 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 6 | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>(7) 8 9 | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 12 | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |

| SITUATION | TOTAL |
|---|---|
| | 40 Slight |

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VEGETATION–SOIL DESCRIPTION

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | 15 | Cushman | 30IZ | Fiecht! | 7 mo 74 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| — | 15 | (29) Sec. 25, T. 56 N, R. 73 W | — | 29 | — | Sandy Shales |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Fort Union | Stone — Rock — | Alkaline Non/sli Saline Non/High Water table None | Residual |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| 4-6% ☐ Single ☒ Complex | W | 4125 | Type Rill-Gully SSF 50 – Class Mod | B |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st , 2nd , 3rd , 4th | — Air — Soil | Days ——> 28° | Well drained | Mod. Slow | Mod. Slow | 18 in | 8.8 (42") |

| 32. HORIZON | 33. THICKNESS | 34. COLOR DRY MOIST MATRIX | 34. MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-1" | (D) 10YR 7/2 (M) 10YR 7/2 | | SiL | m1pl/ m2cr | (D) so (M) lo | — | 2f | — | — | a |
| AB | 1-2" | (D) 10YR 4/2 (M) 10YR 4/2 | | SiL | m1bk/ f1bk | (D) so (M) vfr | — | 2f | — | — | g |
| B21t | 2-6" | (D) 10YR 5/3 (M) 10YR 4/3 | | C | m2pr/ f2bk | (D) h (M) fr | 2m | 2f | — | — | g |
| B22t | 6-10" | (D) 10YR 5/3 (M) 10YR 4/3 | | C | c2pr/ m2bk | (D) h (M) fr | 2m | 2f | — | — | g |
| B3ca | 10-18" | (D) 10YR 6/3 (M) 10YR 5/3 | | SiCL | vc2pr/ m2bk | (D) h (M) fr | — | 2f | — | es | a |
| C1ca | 18-30" | (D) 10YR 7/3 (M) 10YR 6/3 | | SiCL | c2bk/ m2bk | (D) vh (M) fr | — | 1f | — | ev | a |
| C2ca | 30-42" | (D) 10YR 7/4 (M) 10YR 5/4 | 10YR 7/2 10YR 6/2 | SiC | Massive | (D) vh (M) fi | — | — | — | ev | a |
| C3ca | 42-60" | (D) 10YR 7/3 (M) 10YR 6/3 | | CL | Massive | (D) sh (M) fr | — | — | — | es | a |
| C4ca | 60-78" | (D) 10YR 7/2 (M) 10YR 6/2 | | SiL | Massive | (D) h (M) fi | — | — | — | es | g |
| IIC5ca | 78-96" | (D) 10YR 7/3 (M) 10YR 6/3 | 10YR 7/6 10YR 5/6 | SiCL | Massive | (D) eh (M) efi | — | — | — | es | a |
| IIC6ca | 96-120" | (D) 10YR 7/1 (M) 10YR 6/1 | | L | Massive | (D) h (M) vfr | — | — | — | es | — |

118"+ soft fine sands..

18-30" lime accumulations (segregations)

(Instructions inside back cover)

Form 7310–9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: Fiechtl | Date: 7/76
Location: 25, 5 6 N., 73 W
Profile 29
Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS
### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT * | No visual evidence of movement<br>0 1 2 3 | Some movement of soil particles<br>4 5 | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 (7) 8 | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions<br>12 13 14 |
| SURFACE LITTER * | Accumulating in place<br>0 1 2 3 | May show slight movement<br>4 5 (6) | Moderate movement is apparent, deposited against obstacles<br>7 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>12 13 14 |
| SURFACE ROCK * | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 (2) | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>3 4 5 | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 7 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDES-TALLING * | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>4 5 6 | Small rock and plant pedestals occurring in flow patterns<br>7 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 (11) | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS * | No visual evidence of flow patterns<br>0 1 2 3 | Deposition of particles may be in evidence<br>4 5 (6) | Well defined, small, and few with intermittent deposits<br>7 8 9 | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 3 | Some rills in evidence at infrequent intervals over 10'<br>4 5 6 | Rills ½' to 6" deep occur in exposed places at approximately 10' intervals<br>7 8 (9) | Rills ½' to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>0 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 6 | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>7 8 (9) | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 12 | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |

| SITUATION | TOTAL |
|---|---|
| | |
| | |

50 Moderate

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VEGETATION–SOIL DESCRIPTION

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | 15 | Webaux | 8033 | Fiechtl | 7 mo 76 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| -- | 15 | (26) Sec. 30, T. 56N, R. 72W | ---------- | 26 | ------ | Baked Rock |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Wasatch | Stone 15 Rock -- | Alkaline Sli Saline Sli / High Water table None | Residual |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| 4-6% ☐ Single ☑ Complex | N | 4030 | Type Sheet/gully SSF 46 Class mod. | B |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st , 2nd , 3rd , 4th | -- Air -- Soil | Days ---> 28° | Well drained | Mod. Slow - Moderate | Mod. Slow - Moderate | 36 in | 8.8 (4") in |

| 32. HORIZON | 33. THICKNESS | 34. COLOR DRY MOIST — MATRIX | 34. COLOR — MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-2" | (D) 5YR 5/3 (M) 5YR 4/2 | | SiL | c1cr / m1cr | (D) so (M) lo | – | 2f | 15 | | a |
| AB | 2-5" | (D) 5YR 4/3 (M) 5YR 3/3 | | SiL | m1bk / f1bk | (D) sh (M) vfr | – | 2f | 15 | | g |
| B21 | 5-10" | (D) 5YR 5/3 (M) 5YR 4/3 | | SiL | m2pr / m-f1bk | (D) sh (M) vfr | – | 2f | 15 | | g |
| B22 | 10-24" | (D) 5YR 5/3 (M) 5YR 4/3 | | SiL | c1pr / m-f1bk | (D) sh (M) vfr | – | 2f | 15 | | g |
| B3ca | 24-36 | (D) 5YR 6/3 (M) 5YR 5/3 | | SiL | c1bk / m1bk | (D) sh (M) vfr | – | 2f | <5 | | a |
| C1ca | 36-54 | (D) 5YR 6/2 (M) 5YR 5/3 | | SiL | c-vc1bk / m1bk | (D) sh (M) vfr | – | 1 | <5 | | a |
| IIC2ca | 54-72 | (D) 7.5YR 7/2 (M) 5YR 5/3 | | SiL | Massive | (D) sh (M) vfr | – | – | 25 | | a |
| IIC3ca | 72-96 | (D) 7.5YR 7/2 (M) 7.5YR 4/2 | | SiL | Massive | (D) sh (M) vfr | – | – | 25 | | g |
| IIIC4ca | 96-120 | (D) 10YR 6/3 (M) 10YR 5/3 | | SiL | ssh | (D) sh (M) vfr | – | — | | | a |

- mottling influence from 10R 6/8 to 2.5YR 6/8
- profile colors varying 1/2 chips lighter or darker than indicated
- 36-39" transition zone between B3 ca & C ca.
- Sandy shale influence at 72" + –
- Channery granules 1-24", large gravel size material 3"-4" + lime coated.

(Instructions inside back cover)

Form 7310–9a (December 1970)

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By Fiechtl | Date 7/76

Location Profile 26
Sec. 30, 56N, R72W

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS
### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT* | No visual evidence of movement<br>0 1 2 3 | Some movement of soil particles<br>4 (5) | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 7 8 | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions<br>12 13 14 |
| SURFACE LITTER* | Accumulating in place<br>0 1 2 3 | May show slight movement<br>4 5 (6) | Moderate movement is apparent, deposited against obstacles<br>7 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>12 13 14 |
| SURFACE ROCK* | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 2 | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>3 4 5 | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 (7) 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDESTALLING* | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>4 5 (6) | Small rock and plant pedestals occurring in flow patterns<br>7 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 11 | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS* | No visual evidence of flow patterns<br>0 1 2 3 | Deposition of particles may be in evidence<br>4 5 6 | Well defined, small, and few with intermittent deposits<br>(7) 8 9 | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 (3) | Some rills in evidence at infrequent intervals over 10'<br>4 5 6 | Rills ½" to 6" deep occur in exposed places at approximately 10' intervals<br>7 8 9 | Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>0 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 6 | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>7 8 9 | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 (12) | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |

| SITUATION | TOTAL |
|---|---|
| | 46 moderate |

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

**VEGETATION–SOIL DESCRIPTION**

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | 15 | ----------, Wirf | 8034 | Fiecht/ | 7 mo 76 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| -- | 15 | (14) Sec. 31, T. 56N, R. 72W | ---------- | --14 | ------ | Sandstone |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Fort Union | Stone -- Rock -- | Alkaline Sli – Mod Saline Non – Sli Water table None | Residual |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| 2-4 ☐ Single ☑ Complex | N | 4235 | Type Sheet SSF 40 Class Sli | B |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st , 2nd , 3rd , 4th | -- Air -- Soil | Days ---> 28° | Well drained | Mod. Slow-Moderate | Mod. Slow-Moderate | 15 in | 8.8(4") in |

| 32. HORIZON | 33. THICKNESS | 34. COLOR DRY MOIST — MATRIX | 34. COLOR DRY MOIST — MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-1" | (D) 10YR 6/2 (M) 10YR 4/2 | | SiL | 2 cpl / 2 m gr | (D) so (M) fr | — | 2f | — | — | a |
| AB | 1-3" | (D) 10YR 6/2 (M) 10YR 5/3 | | CL | m 2 bk / f 2 bk | (D) sh (M) fr | — | 2f | — | — | g |
| Bzt | 3-6" | (D) 10YR 5/2 (M) 10YR 4/2 | | CL | m 2 pr / f-m 2 bk | (D) sh (M) fr | | 2f | — | — | g |
| Bzca | 6-15" | (D) 10YR 6/2 (M) 10YR 4/2 | | SiCL | m 2 pr / m 2 bk | (D) h (M) fr | — | 2f | — | e | g |
| C1ca | 15-18" | (D) 10YR 7/2 (M) 10YR 6/2 | | SiCL | c 1 pr / m 2 bk | (D) h (M) fr | — | 1f | — | ev | g |
| C2ca | 18-36 | (D) 10YR 7/2 (M) 2.5Y 6/2 | | CL | Massive | (D) h (M) fr | — | 1f | — | ev | a |
| C3ca | 36-54 | (D) 10YR 7/1 (M) 10YR 6/2 | | L | Massive | (D) vh (M) fi | — | — | — | ev | a |
| C4ca | 54-72 | (D) 10YR 7/2 (M) 10YR 6/2 | 10YR 8/8 10YR 5/8 | SiL | Massive | (D) vh (M) fi | — | — | — | ev | g |
| C5 | 72-96 | (D) 10YR 7/1 (M) 10YR 5/2 | 10YR 8/8 10YR 5/8 | VFSL | Massive | (D) vh (M) fi | — | — | — | e | g |
| C6 | 96-120 | (D) 10YR 7/1 (M) 10YR 7/2 | 10YR 8/8 10YR 5/8 | SiCL | Massive | (D) vh (M) fi | — | — | — | e | |

15"+ Lime nettings & accumulations

36"+ Dense - consolidated sandy shales

18-84" Sandy deposits

Vegetation: W. Wheat, Grasses, G. Needle, J. Grass, Sage

(Instructions inside back cover)

Form 7310–9a (December 1970)

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: Fiechtl
Date: 7/76
Location: Proposed 1-4
Sec. 31, T. 56N., R. 72W
Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS
### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT* | No visual evidence of movement<br>0 1 2 3 | Some movement of soil particles<br>4 5 | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 7 8 | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions<br>12 13 14 |
| SURFACE LITTER* | Accumulating in place<br>0 1 2 3 | May show slight movement<br>4 5 6 | Moderate movement is apparent, deposited against obstacles<br>7 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>12 13 14 |
| SURFACE ROCK* | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 2 | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>3 4 5 | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 7 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDESTALLING* | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>4 5 6 | Small rock and plant pedestals occurring in flow patterns<br>7 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 11 | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS* | No visual evidence of flow patterns<br>0 1 2 3 | Deposition of particles may be in evidence<br>4 5 6 | Well defined, small, and few with intermittent deposits<br>7 8 9 | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 3 | Some rills in evidence at infrequent intervals over 10'<br>4 5 6 | Rills ½' to 6" deep occur in exposed places at approximately 10' intervals<br>7 8 9 | Rills ½' to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>0 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 6 | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>7 8 9 | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 12 | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |

| SITUATION | TOTAL |
|---|---|
| | 40 Slight |

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VEGETATION–SOIL DESCRIPTION

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | 15 | ---------- / Shingle | 8029 | Fiechtl | 7 mo 76 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| / | 15 | (13) Sec. 31, T. 56N, R. 72W | ---------- | 13 | ------ | Sandy Stone |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Fort Union | Stone – Rock – | Alkaline slight Saline sli/mod Water table None | Residual |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| 4-6% ☐ Single ☑ Complex | N | 4240 | Type Rill SSF 44 Class Mod. | B |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st , 2nd , 3rd , 4th | – – Air – – Soil | Days – – –> 28° | Well drained | Mod. Slow - Moderate | Mod. Slow - Moderate | 18 in | 8.8 (4") |

| 32. HORIZON | 33. THICKNESS (in / m) | 34. COLOR DRY / MOIST — MATRIX | 34. COLOR — MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-5 (4 / .13) | (D) 10YR 7/3 (M) 10YR 6/3 | | SiCL | m1bk / vf1gr | (D) lo (M) lo. | — | 3 | — | e | g |
| C1ca | 5-9 (.23) | (D) 10YR 7/2 (M) 10YR 6/2 | | SiCL | c2pl / f2abk | (D) sh (M) fr | — | 3 | — | ev | a |
| C2ca | 9-18 (.46) | (D) 10YR 6/3 (M) 10YR 5/3 | | SiL | c2pl / m2abk | (D) sh (M) fr | — | 2 | — | ev | a |
| C3ca | 18-30 (.76) | (D) 10YR 7/2 (M) 10YR 6/2 | | <SiCL | vc-c2pl / c2pl | (D) sh (M) fr | — | 1 | — | ev | g |
| C4ca | 30-48 (1.2) | (D) 10YR 7/2 (M) 10YR 6/2 | | <SiCL | ssh | (D) h (M) vfi | — | — | — | ev | g |
| C5ca | 48-60 (1.5) | (D) 10YR 6/3 (M) 10YR 5/3 | | SiL | ssh | (D) h (M) vfi | — | — | — | ev | d |
| C6ca | 60-84 (2.1) | (D) 10YR 7/2 (M) 10YR 6/2 | | L | ssh | (D) vh (M) efi | — | — | — | e | a |
| C7 | 84-102 (2.6) | (D) 10YR 7/2 (M) 10YR 6/3 | 10YR 5/4 | SiCL | ssh | (D) vh (M) efi | — | — | — | e | a |
| C8 | 102-120 (3.0) | (D) 10YR 7/3 (M) 10YR 6/3 | 10YR 5/4 | SiCL | ssh | (D) vh (M) efi | — | — | — | e | — |

Small thin pockets of blue shale in area at 96"+.
Salt crystals noticible at 18"+ Salt accumulation at 102"+..
Vegetation: Grass, W. Wheat, G. Needle, P. Juno, Scattered sage.
ssh - strongly sandy shales

(Instructions inside back cover)

Form 7310–9a (December 1970)

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By Fiechtl | Date 7/76

Location Profile 13
Sec. 31, T. 56 N., R. 72 W.

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT* | No visual evidence of movement<br>0 1 2 3 | Some movement of soil particles<br>4 5 | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 7 (8) | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions<br>12 13 14 |
| SURFACE LITTER* | Accumulating in place<br>0 1 2 3 | May show slight movement<br>4 5 6 | Moderate movement is apparent, deposited against obstacles<br>7 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>(12) 13 14 |
| SURFACE ROCK* | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 2 | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>(3) 4 5 | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 7 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDES-TALLING* | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>4 5 6 | Small rock and plant pedestals occurring in flow patterns<br>(7) 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 11 | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS* | No visual evidence of flow patterns<br>0 1 2 3 | Deposition of particles may be in evidence<br>4 5 6 | Well defined, small, and few with intermittent deposits<br>7 8 (9) | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 3 | Some rills in evidence at infrequent intervals over 10'<br>4 5 6 | Rills ½' to 6" deep occur in exposed places at approximately 10' intervals<br>(7) 8 9 | Rills ½' to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>(0) 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 6 | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>7 8 9 | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 12 | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |

| SITUATION | TOTAL | | | | |
|---|---|---|---|---|---|
| | | | 46 | Moderate | |

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VEGETATION–SOIL DESCRIPTION

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | 15 | Dillingson | 8026 | Fiechtl | 7 mo 76 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| — | 15 | (15) Sec. 31, T. 56N, R. 72W | — | 15 | — | Baked Rock |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Wasatch | Stone 15 Rock — | Alkaline Sli. Saline Non-Sli. Water table none | Colluvial |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| — ☐ Single ☑ Complex | S | 4160 | Type Sheet SSF 28 Class Sli. | B |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st, 2nd, 3rd, 4th | — Air — Soil | Days ——> 28° | Well drained | Mod. Slow - Moderate | Mod. Slow - Moderate | 24 in | 8.8 (4') in |

| 32. HORIZON | 33. THICKNESS | 34. COLOR DRY MOIST — MATRIX | 34. COLOR DRY MOIST — MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-3 | (D) 5YR5/3 (M) 5YR3/3 | | SiL | c1pl/ m1gk | (D) so (M) vfr | — | 2 | 15 | — | a |
| AB | 3-7 | (D) 5YR5/3 (M) 5YR3/3 | | L | c1pk/ f-m2LK | (D) sh (M) fr | — | 2 | 15 | — | g |
| B21t | 7-12 | (D) 5YR5/3 (M) 5YR3/4 | | L | m1/2 pr/ f2bK | (D) h (M) fr | 1n | 2 | 15 | — | g |
| B22t | 12-24 | (D) 5YR5/3 (M) 5YR4/3 | | CL | c2pr/ m2bK | (D) h (M) fr | 2n | 2 | — | — | g |
| B3ca | 24-42 | (D) 5YR5/3 (M) 5YR4/3 | | CL | c2pr/ m2bK | (D) h (M) fr | — | 1 | — | ev | g |
| Cca1 | 42-60 | (D) 7.5YR6/3 (M) 7.5YR4/3 | | SiL | Massive | (D) sh (M) fr | — | 1 | — | ev | g |
| 2 | 60-78 | (D) 5YR6/3 (M) 5YR5/3 | | SiL | Massive | (D) sh (M) vfr | — | — | — | ev | g |
| IIC1 | 78-102 | (D) 5YR5/4 (M) 5YR4/4 | | L | Massive | (D) sh (M) vfr | — | — | 15 | ev | a |
| 2 | 102-120 | (D) 2.5Y6/4 (M) 2.5Y4/3 | | grL | Massive | (D) sh (M) vfr | — | — | 25+ | ev | a |

42-60" fine lime mottlings with lime accumulations

78-120"+ granules baked with 2' clinkers

Mottling influence from 2.5YR 5/6 to 4/2 for surface & subsurface

to 2.5YR 5/6-4/6 & 2.5YR 6/8-4/8 in subhorizons..

Vegetation: Grama, W. Wheat, G. Needle, Brome, various forbes & fescue

(Instructions inside back cover)

Form 7310-9a (December 1970)

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: Fiechtl
Date: 7-6
Location: Profile 15
Sec. 31, T 56N, R 72W.
Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT* | No visual evidence of movement<br>0 1 2 (3) | Some movement of soil particlea<br>4 5 | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 7 8 | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions<br>12 13 14 |
| SURFACE LITTER* | Accumulating in place<br>0 1 2 3 | May show slight movement<br>4 5 (6) | Moderate movement is apparent, depoaited againat obstacles<br>7 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>12 13 14 |
| SURFACE ROCK* | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 2 | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>(3) 4 5 | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 7 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDESTALLING* | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>(4) 5 6 | Small rock and plant pedestala occurring in flow patterns<br>7 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 11 | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS* | No visual evidence of flow patterns<br>0 1 2 (3) | Deposition of particles may be in evidence<br>4 5 6 | Well defined, amall, and few with intermittent deposits<br>7 8 9 | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 (3) | Some rills in evidence at infrequent intervals over 10'<br>4 5 6 | Rills ½" to 6" deep occur in exposed places at approximately 10' intervals<br>7 8 9 | Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>0 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 (6) | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>7 8 9 | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 12 | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |
| SITUATION | TOTAL | | | | |
| | | 25 Slight | | | |

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VEGETATION–SOIL DESCRIPTION

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | L5 | / Bidman | 8024 | Fiechtl | 7 mo 76 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| 1 | 15 | (24) Sec. 30, T. 56 N, R. 72 W | | 24 | | Baked Rock |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Wasatch | Stone — Rock — | Alkaline Non-Mod Saline Non-High Water table None | Colluvial |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| 2-4 ☐ Single ☑ Complex | N | 4020 | None Type. Sheet SSF 37 Class Sli. | B |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st, 2nd, 3rd, 4th | — Air — Soil | Days ——> 28° | Well drained | Mod. Slow. Moderate | Mod. Slow. Moderate | 19 in | 8.8" (4') |

| 32. HORIZON | 33. THICKNESS | 34. COLOR DRY MOIST — MATRIX | 34. COLOR DRY MOIST — MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-2" | (D) 10YR 6/2 (M) 10YR 4/2 | | SiL | f1bk/ m1cr | (D) so (M) lo | — | 2 | — | — | a |
| AB | 2-4" | (D) 10YR 5/3 (M) 10YR 4/3 | | CL | m1bk/ f1bk | (D) sh (M) fr | 1 | 2 | — | — | g |
| B21t | 4-7" | (D) 10YR 5/2 (M) 10YR 4/2 | | SiCL | m2pr/ f2bk | (D) h (M) fr | 3 | 2 | — | — | g |
| B22t | 7-15" | (D) 10YR 5/3 (M) 10YR 4/2 | | SiC | m2pr/ m2bk | (D) h (M) fr | 3 | 2 | — | — | g |
| B3ca | 15-19" | (D) 10YR 5/2 (M) 10YR 4/2 | | SiCL | c1pr/ c2bk | (D) vh (M) fr | — | 2 | — | ev | a |
| C1ca | 19-42 | (D) 10YR 6/3 (M) 10YR 4/3 | | SiCL | vc1bk/ c1bk | (D) h (M) fr | — | 1 | — | ev | g |
| C2ca | 42-60 | (D) 7.5YR 5/3 (M) 7.5YR 4/3 | | L | Massive | (D) sh (M) ffr | — | 1 | — | ev | g |
| IIC3ca | 60-72 | (D) 7.5YR 6/3 (M) 7.5YR 5/3 | | grSL | Massive | (D) h (M) lo | — | — | 25-50% | ev | — |

19-42" fine lime nettings with intermittent lime accumulations
42"+ influenced from Wasatch formation
A2 surface horizon in the area.

(Instructions inside back cover)

Form 7310–9a (December 1970)

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: Fiechtl | Date: 7/76

Location: Profile 24
Sec. 30, T. 56 N., R. 72 W

Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS
### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT* | No visual evidence of movement<br>0 1 2 3 | Some movement of soil particles<br>4 (5) | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 7 8 | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind, scoured depressions<br>12 13 14 |
| SURFACE LITTER* | Accumulating in place<br>0 1 2 (3) | May show slight movement<br>4 5 6 | Moderate movement is apparent, deposited against obstacles<br>7 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>12 13 14 |
| SURFACE ROCK* | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 2 | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>(3) 4 5 | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 7 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDES-TALLING* | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>4 5 6 | Small rock and plant pedestals occurring in flow patterns<br>(7) 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 11 | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS* | No visual evidence of flow patterns<br>0 1 2 3 | Deposition of particles may be in evidence<br>4 5 (6) | Well defined, small, and few with intermittent deposits<br>7 8 9 | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 3 | Some rills in evidence at infrequent intervals over 10'<br>4 5 6 | Rills ½" to 6" deep occur in exposed places at approximately 10' intervals<br>(7) 8 9 | Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>0 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 (6) | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>7 8 9 | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 12 | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |

| SITUATION | TOTAL | | | | |
|---|---|---|---|---|---|
| | | | 37 slight | | |

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VEGETATION–SOIL DESCRIPTION

| 1. State | 2. District | 3. Planning Unit | 4. Vegetation–Soil Unit | 5. Soil Map Symbol | 6. Surname | 7. Date |
|---|---|---|---|---|---|---|
| WY | 06 | L5 | ---------- / Fort Collins | 8027 | Fiecht! | 7 mo 76 yr |

| 8. Area | 9. County | 10. Location | 11. Photo No. | 12. Writeup No. | 13. File No. | 14. Parent Rock |
|---|---|---|---|---|---|---|
| -- | L5 | (28) Sec. 25, T. 56N, R. 73W | ---------- | 28 | ------ | Sandy Shales |

| 15. Formation Name | 16. Surface Conditions (percent) | 17. Land Conditions | 18. Landform |
|---|---|---|---|
| Fort Union | Stone -- Rock -- | Alkaline Non Saline Non/mod Water table None | Colluvial |

| 19. Slope (percent) | 20. Aspect | 21. Elevation | 22. Present Erosion | 23. Hydrologic Group |
|---|---|---|---|---|
| 2-4% ☐ Single ☑ Complex | SW | 4140 | Type Rill & Gully SSF 4 Class - | B - |

| 24. Precipitation (in) | 25. Temperature | 26. Frost-free | 27. Drainage Class | 28. Infiltration | 29. Percolation | 30. ERD | 31. AWC |
|---|---|---|---|---|---|---|---|
| 15.7 1st , 2nd , 3rd , 4th | -- Air -- Soil | Days ---> 28° | Well drained | Mod. Slow | Mod. Slow | 2L in | 8.8" (v') in |

| 32. HORIZON | 33. THICKNESS | 34. COLOR DRY MOIST — MATRIX | 34. COLOR DRY MOIST — MOTTLING | 35. TEXTURE | 36. STRUCTURE | 37. CONSISTENCY DRY MOIST | 38. CLAY FILMS | 39. ROOTS | 40. STONES % VOL. | 41. REACTION (pH) | 42. BOUNDARY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-3" | (D) 10YR 6/2 (M) 10YR 4/3 | | SiL | 1 f cr | (D) sh (M) lo | — | 2 | — | — | g |
| B12 | 3-7" | (D) 10YR 5/3 (M) 10YR 4/2 | | SiCL | m 2 prl m 2 bk | (D) h (M) fr | — | 2 | — | — | a |
| B22t | 7-17" | (D) 10YR 5/3 (M) 10YR 4/3 | | SiCL | m 2 prl m-f 2 bk | (D) vh (M) fr | 3 m pf | 2 | — | — | a |
| B3 | 17-21" | (D) 10YR 5/3 (M) 10YR 4/2 | | SiCL | c 2 prl c 2 bk | (D) vh (M) fr | — | 2 | — | — | a |
| C1ca | 21-36" | (D) 10YR 6/2 (M) 10YR 5/2 | | SiCL | vc 2 bk / c-m 2 bk | (D) vh (M) fr | — | 1 | — | ev | g |
| C2ca | 36-54" | (D) 10YR 6/3 (M) 10YR 5/4 | 7.5YR 5/4 | SiCL | vc 2 bk / c-m 2 bk | (D) sh (M) fr | — | 1 | — | ev | a |
| C3ca | 54-78" | (D) 10YR 7/2 (M) 10YR 6/3 | 7.5YR 5/6 | CL | ssh | (D) vh (M) vfr | — | — | — | ev | a |
| C4 | 78-102" | (D) 7.5YR 6/2 (M) 7.5YR 5/2 | | SiCL | " | (D) eh (M) fi | — | — | — | ve | g |
| C5 | 102-120" | (D) 10YR 7/2 (M) 10YR 6/2 | | CL | " | (D) eh (M) efi | — | — | — | e | |

ssh - sandy shales

36-54" contains flakes of mottled sandy shale

24-36" lime nettings & lime accumulations

54-84" showing old root casts

Vegetation: Blue Grama, Green Needle, Western Wheat, Prairie June and Big Sage

Grass 45% ot; Sage 40%, Forbes <5%, Bare Surface 10%

(Instructions inside back cover)

Form 7310–9a (December 1970)

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: Fiechtl
Date: 7/76
Location: Profile 28 Sec. 25, T. 56 N., R. 73 W.
Treatment affecting the SSF

## DETERMINATION OF EROSION CONDITION CLASS

### SOIL SURFACE FACTORS (SSF)

| | | | | | |
|---|---|---|---|---|---|
| SOIL MOVEMENT * | No visual evidence of movement<br>0 1 2 3 | Some movement of soil particles<br>4 5 | Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.<br>6 (7) 8 | Occurs with each event. Soil and debris deposited against minor obstructions.<br>9 10 11 | Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions<br>12 13 14 |
| SURFACE LITTER * | Accumulating in place<br>0 1 2 3 | May show slight movement<br>4 5 6 | Moderate movement is apparent, deposited against obstacles<br>(7) 8 | Extreme movement apparent, large and numerous deposits against obstacles<br>9 10 11 | Very little remaining *(use care on low productive sites)*<br>12 13 14 |
| SURFACE ROCK * | If present, the distribution of fragments show no movement caused by wind or water<br>0 1 (2) | If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water<br>3 4 5 | If present, fragments have a poorly developed distribution pattern caused by wind or water<br>6 7 8 | If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles<br>9 10 11 | If present, surface rock or fragments are dissected by rills and gullies or are already washed away<br>12 13 14 |
| PEDESTALLING * | No visual evidence of pedestalling<br>0 1 2 3 | Slight pedestalling, in flow patterns<br>4 5 6 | Small rock and plant pedestals occurring in flow patterns<br>(7) 8 9 | Rocks and plants on pedestals generally evident, plant roots exposed<br>10 11 | Most rocks and plants pedestalled and roots exposed<br>12 13 14 |
| FLOW PATTERNS * | No visual evidence of flow patterns<br>0 1 2 3 | Deposition of particles may be in evidence<br>4 (5) 6 | Well defined, small, and few with intermittent deposits<br>7 8 9 | Flow patterns contain silt and sand deposits and alluvial fans<br>10 11 12 | Flow patterns are numerous and readily noticeable. May have large barren fan deposits.<br>13 14 15 |
| RILLS | No visual evidence of rills<br>0 1 2 3 | Some rills in evidence at infrequent intervals over 10'<br>4 (5) 6 | Rills ½" to 6" deep occur in exposed places at approximately 10' intervals<br>7 8 9 | Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10'<br>10 11 12 | May be present at 3" to 6" deep at intervals less than 5'<br>13 14 |
| GULLIES | May be present in stable condition. Vegetation on channel bed and side slopes<br>0 1 2 3 | A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.<br>4 5 6 | Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.<br>7 (8) 9 | Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length<br>10 11 12 | Sharply incised gullies cover most of the area and over 50% are actively eroding<br>13 14 15 |

| SITUATION | TOTAL | | | | |
|---|---|---|---|---|---|
| | | | ill moderate | | |

*Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

*(Instructions on reverse)*

# LABORATORY ANALYSES AND PROCEDURES

Disturbed Hydraulic Conductivity was determined by the use of plastic tubes (Richards, et. al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 34b:112-113).

pH of 1:15 Soil Suspension (Richards, et. al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical of Soils, 1964)

pH Reading in $CACl_2$ Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

Saturation Extract taken from saturation soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 2 and 3:84-88, 27:107 and 4:89-90), C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical of Soils, 1964).

Carbonates and bicarbonates were determined by acid titration and chlorides were determined by the Mohr volumetric method (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 82:145-146 and 84:146), C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1: 945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical of Soils, 1964), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis chloride only, p. 69).

Sodium, Potassium, Calcium and Magnesium were determined by atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973) and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133, and 143).

Nitrate was determined by phenoldsulfonic acid (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 15:100), (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy 84-5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, 133:233-237).

Exchangeable Sodium and Potassium were extracted by ammonium acetate solution. Cation-Exchange Capacity was extracted by ammonium acetate and sodium acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 72-3:1033, 72-3.2.1:1033-1034 and 57-1:891-895).

Exchangeable Sodium Percentage was determined by calculation (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 20a:101).

Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et. al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22c:104).

Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22d: 104-105).

Boron was determined by extracting with hot water (Bear, et al., Chemical of Soils, 490-494) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063).

Trace Metals were determined by atomic absorption either by flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases,"Book 5 - Laboratory Analysis, 50-157) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition).

Organic Carbon - The Walkley-Block method is used, and diphenylamine is the indicator. (Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 90-3:1372-1375).

Bulk Density - Clod method. Density measured by water displacement. (Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 30-4:381-383).

Moisture Retention was determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

Particle-Size Analyses were determined by pipeting analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 41:122-124).

# GLOSSARY

Annual Plant (annuals), A plant that completes its life cycle and dies in 1 year or less.

Aspect, The direction toward which a slope faces. Exposure.

Available Nutrient, The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water, The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock, Any part of the consolidated geologic formation, soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding, Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer, Substances in soil or water that act chemically to resist changes in reaction or pH.

Calcareous Soil, Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water, The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization, Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Compaction, The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop (See Nurse Crop)

Conifer, A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour, An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant, A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous, Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling, Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage, The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand, Density of stocking expressed in number of trees per acre.

Broadcast Seeding, A method of establishing a stand of vegetation by sowing seed on the ground surface.

Dissolved Solids, The difference between the total and suspended solids in water.

Disturbed Land, Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer, Tractor with a stell plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology, The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem, A total organic community in a defined area or time frame.

Effective Precipitation, That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent, Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment, All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility, The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion, The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition), A chemical element required for the normal growth of plants.

Evapotranspiration, A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation, The act of removing overburden material.

Fertilizer, Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade, The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid ($P_2O_5$), and 5 percent water-soluble potash ($K_2O$). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer (nitrogen (N), phosphorous (P), and potassium (K)).

Fill, Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage, Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land, Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minimum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on farms are commonly called woodland or farm forests.

Germination, Sprouting; beginning of growth.

Gradation, A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size, Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover, Any living or dead vegetative material producing a protecting mat on or just above the soil surface.

Ground Water, Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called plerotic water; phreatic water.

Growing Season, Determined by the Lowery-Johnson Method.

Gully Erosion, Removal of soil by running water, with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding, Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious, Prohibits fluid flow.

Infiltration, Water entering the ground water system through the land surface.

Intermittent Stream, A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification, Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning, The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching, The removal of materials in solution by the passage of water through soil.

Leachate, Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume, A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime, Lime, from from the strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural line are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

| | |
|---|---|
| Quicklime | - limestone + heat (calcined) $CaO$ |
| Hydrated lime | - quicklime + $H_2O$ $Ca(OH)_2$ |
| Slaked lime | - same as hydrated but slaking equipment is used for adding water |
| Milk of lime | - water mixture containing lime in solution + lime in suspension |

Micro-Climate, A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients, Nutrients in only small, trace, or minute amounts.

Mined-Land, Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch, A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation, Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural Seeding (Volunteer), Natural distribution of seed over an area.

Neutralization, The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil, A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation, The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop, A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives way to the permanent crop. Sometimes referred to as a companion crop.

Nutrients, Any element taken into a plant that is essential to its growth.

Overburden, The earth, rock, and other materials which lie above the coal.

Percolation, Downward movement of water through soils.

Permeability, The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH, The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume.

Pollution, Environmental degradation resulting from man's activities or natural events.

Pond, A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land, The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate, Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation, The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile, The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land, Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation, The natural or artificial restocking of an area with forest trees.

Regrading, The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation, Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Revegetation, Plants or growth which replaces original ground cover following land disturbance.

Ripping, The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff, That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil, A soil having a combination of a harmful quantity of salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil, A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone, A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation, Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment, Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin, A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed, The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seep, A more or less poorly defined area where water oozes from the earth in small quantities.

Shale, Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt, Small mineral soil grains the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil), Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Conserving Crops, Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity, The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile, A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure, The combination or arrangement of primary soil particles into secondary particles, units, or beds.

Solum, The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil, The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile), Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.

Stratified, Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip, To mine a deposit by first taking off the overlying burden.

Strip Mine, Refers to a procedure of mining which entails the complete removal of all material from over the product to be mined in a series of rows or strips; also referred to as "open cut," "open pit," or "surface mine."

Strip Mining (See Surface Mining)

Stripping, The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil, The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum, Alluvial, colluvial and bedrock material that lies below the soil profile.

Surface Soil, That part of the upper soil of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 inches) in non-arable soils.

Suspended Solids, Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace, Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope, A slope that is intersected by one or more terraces.

Texture, The character, arrangement and mode of aggregation of particles which make up the earth's surface.

Topdressing Material, Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth, The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography, The shape of the ground surface, such as hills, mountains or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil), Includes acid spoil with pH below 4.0. Also refers to spoil having amounts of minerals such as aluminum, manganese, and iron that adversely affect plant growth.

Transpiration, The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material), Soil material in a form of loose aggregation.

Vegetation, General term including grasses, legumes, shrubs, trees naturally occurring and planted intentionally.

Vegetative Cover, The entire vegetative canopy on an area.

Volunteer, Springing up spontaneously or without being planted; a volunteer plant.

Weathering, The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife, Undomesticated vertebrate animals, except fish, considered collectively.

# APPENDIX E

# GREENHOUSE

White Tail Butte Greenhouse Data.

| Sample No. | Depth (in) | Pot Wt. (Kg) | Germination: Days After Seeding for Ten Plants to Emerge I | Germination: Days After Seeding for Ten Plants to Emerge II | Germination: Number of Seeds Germinated I | Germination: Number of Seeds Germinated II | Salt Crust at Germination | Salt Crust at Harvest | Harvest: Plant Dry Weight (gm) I | Harvest: Plant Dry Weight (gm) II | Harvest: Relative Yield (%) | Harvest: Average Plant Height (cm) I | Harvest: Average Plant Height (cm) II | Black Leaf Tips | Soil Surface Cracks | Field Cap. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T-894 | 0 - 24 | 2.0 | 5 | 6 | 38 | 38 | 1 | 0 | 3.26 | 3.00 | 70 | 29 | 29 | 0 | 0 | 14.2 |
| T-895 | 21 - 36 | 2.0 | 6 | 6 | 34 | 31 | 1 | 0 | 3.74 | 2.88 | 74 | 35 | 31 | 0 | 1 | 18.3 |
| T-896 | 36 - 54 | 2.0 | 6 | 6 | 38 | 38 | 1 | 0 | 1.99 | 2.16 | 47 | 30 | 30 | 0 | 1 | 16.1 |
| T-897 | 54 - 78 | 2.0 | 7 | 7 | 34 | 24 | 1 | 0 | 1.53 | 1.76 | 37 | 25 | 26 | 2 | 1 | 15.4 |
| T-898 | 78 - 102 | 2.0 | 7 | 7 | 34 | 29 | 1 | 0 | 1.73 | 3.36 | 57 | 29 | 30 | 2 | 0 | 18.7 |
| T-899 | 102 - 120 | 2.0 | 7 | 7 | 35 | 34 | 1 | 0 | 2.72 | 2.96 | 64 | 28 | 33 | 2 | 1 | 19.8 |
| | | | | | | | | | | | | | | | | |
| T-900 | 0 - 9 | 2.0 | 5 | 5 | 34 | 38 | 1 | 0 | 2.89 | 3.37 | 70 | 31 | 31 | 0 | 0 | 20.8 |
| T-901 | 9 - 18 | 2.0 | 6 | 7 | 37 | 31 | 1 | 0 | 3.48 | 2.98 | 72 | 31 | 30 | 1 | 0 | 16.3 |
| T-902 | 18 - 30 | 2.0 | 5 | 6 | 35 | 34 | 1 | 0 | 2.17 | 2.17 | 49 | 27 | 29 | 0 | 1 | 18.8 |
| T-903 | 30 - 48 | 2.0 | 6 | 7 | 34 | 22 | 2 | 1 | 1.96 | 2.58 | 51 | 28 | 28 | 0 | 1 | 21.2 |
| T-904 | 48 - 60 | 2.0 | 7 | 8 | 32 | 26 | 2 | 1 | 1.65 | 0.99 | 30 | 26 | 22 | 0 | 1 | 17.6 |
| T-905 | 60 - 84 | 2.0 | 7 | 7 | 36 | 33 | 2 | 0 | 2.10 | 2.15 | 48 | 25 | 28 | 1 | 0 | 19.8 |
| T-906 | 84 - 102 | 2.0 | 5 | 5 | 36 | 35 | 2 | 0 | 2.36 | 3.07 | 61 | 32 | 32 | 2 | 1 | 20.8 |
| T-907 | 102 - 120 | 2.0 | 6 | 6 | 35 | 33 | 0 | 0 | 2.62 | 2.06 | 52 | 29 | 28 | 3 | 2 | 18.8 |
| | | | | | | | | | | | | | | | | |
| T-914 | 0 - 7 | 2.0 | 5 | 5 | 40 | 38 | 1 | 0 | 3.98 | 2.78 | 76 | 31 | 31 | 1 | 0 | 18.2 |
| T-915 | 7 - 19 | 2.0 | 5 | 5 | 35 | 37 | 1 | 0 | 3.13 | 3.85 | 78 | 32 | 32 | 0 | 0 | 15.9 |
| T-916 | 19 - 42 | 2.0 | 5 | 5 | 37 | 38 | 1 | 0 | 3.22 | 3.42 | 74 | 32 | 32 | 0 | 1 | 20.3 |
| T-917 | 42 - 60 | 2.0 | 7 | 7 | 31 | 30 | 1 | 0 | 2.08 | 2.05 | 46 | 26 | 27 | 0 | 0 | 15.3 |

White Tail Butte Greenhouse Data.

| Sample No. | Depth (in). | Pot Wt. (Kg) | Germination: Days After Seeding for Ten Plants to Emerge | | Germination: Number of Seeds Germinated | | Salt Crust at Germination | Salt Crust at Harvest | Harvest: Plant Dry Weight (gm) | | Harvest: Relative Yield (%) | Harvest: Average Plant Height (cm) | | Black Leaf Tips | Soil Surface Cracks | Field Cap. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | I | II | I | II | | | I | II | | I | II | | | |
| T-918 | 60 - 72 | 2.0 | 7 | 7 | 25 | 40 | 1 | 2 | 0.81 | 1.20 | 23 | 20 | 21 | 1 | 0 | 14.5 |
| | | | | | | | | | | | | | | | | |
| T-919 | 0 - 6 | 2.0 | 5 | 5 | 37 | 38 | 1 | 0 | 2.49 | 2.69 | 58 | 26 | 28 | 0 | 0 | 15.6 |
| T-920 | 7 - 18 | 2.0 | 6 | 6 | 33 | 36 | 1 | 0 | 1.48 | 1.85 | 37 | 28 | 26 | 0 | 0 | 14.5 |
| T-921 | 18 - 30 | 2.0 | 6 | 6 | 38 | 37 | 0 | 0 | 2.21 | 2.39 | 52 | 29 | 30 | 1 | 0 | 18.5 |
| T-922 | 30 - 54 | 2.0 | 7 | 7 | 31 | 36 | 1 | 1 | 2.16 | 2.74 | 55 | 27 | 29 | 0 | 1 | 19.8 |
| T-923 | 54 - 78 | 2.0 | 7 | 7 | 34 | 32 | 1 | 0 | 2.17 | 2.59 | 65 | 29 | 29 | 1 | 1 | 22.3 |
| | | | | | | | | | | | | | | | | |
| T-924 | 0 - 6 | 2.0 | 5 | 5 | 35 | 36 | 1 | 0 | 3.13 | 2.66 | 65 | 32 | 31 | 0 | 0 | 15.7 |
| T-925 | 6 - 18 | 2.0 | 5 | 5 | 36 | 38 | 1 | 0 | 2.76 | 2.91 | 64 | 28 | 28 | 0 | 0 | 20.0 |
| T-926 | 18 - 36 | 2.0 | 7 | 7 | 34 | 31 | 1 | 0 | 1.95 | 1.98 | 44 | 29 | 29 | 0 | 0 | 17.1 |
| T-927 | 36 - 54 | 2.0 | 5 | 5 | 37 | 38 | 1 | 0 | 3.75 | 3.85 | 85 | 32 | 32 | 0 | 0 | 18.5 |
| T-928 | 54 - 72 | 2.0 | 7 | 7 | 37 | 32 | 1 | 0 | 2.69 | 2.70 | 60 | 30 | 30 | 2 | 1 | 17.4 |
| T-929 | 72 - 96 | 2.0 | 7 | 7 | 31 | 31 | 1 | 1 | 1.61 | 1.32 | 33 | 25 | 25 | 1 | 1 | 12.2 |
| T-930 | 96 - 120 | 2.0 | 8 | 8 | 24 | 28 | 1 | 0 | 1.40 | 1.59 | 35 | 27 | 26 | 0 | 1 | 16.8 |
| | | | | | | | | | | | | | | | | |
| T-931 | 0 - 24 | 2.0 | 5 | 5 | 37 | 36 | 0 | 0 | 3.51 | 3.83 | 82 | 30 | 31 | 0 | 0 | 20.8 |
| T-932 | 24 - 42 | 2.0 | 7 | 7 | 36 | 36 | 0 | 0 | 2.21 | 2.03 | 48 | 26 | 32 | 0 | 1 | 16.9 |
| T-933 | 42 - 60 | 2.0 | 7 | 8 | 34 | 31 | 1 | 0 | 2.74 | 2.78 | 62 | 32 | 30 | 1 | 0 | 18.6 |
| T-934 | 60 - 78 | 2.0 | 7 | 8 | 35 | 24 | 0 | 0 | 1.78 | 1.66 | 39 | 27 | 27 | 0 | 0 | 17.4 |

Table 28
Sheet 2 of 6

White Tail Butte Greenhouse Data.

| Sample No. | Depth (in). | Pot Wt. (Kg) | Germination: Days After Seeding for Ten Plants to Emerge I | Germination: Days After Seeding for Ten Plants to Emerge II | Germination: Number of Seeds Germinated I | Germination: Number of Seeds Germinated II | Salt Crust at Germination | Salt Crust at Harvest | Harvest: Plant Dry Weight (gm) I | Harvest: Plant Dry Weight (gm) II | Harvest: Relative Yield (%) | Harvest: Average Plant Height (cm) I | Harvest: Average Plant Height (cm) II | Black Leaf Tips | Soil Surface Cracks | Field Cap. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T-935 | 78 - 102 | 2.0 | 7 | 7 | 24 | 27 | 0 | 0 | 1.73 | 1.49 | 42 | 26 | 27 | 1 | 0 | 16.6 |
| T-936 | 102 - 120 | 2.0 | 7 | 7 | 33 | 32 | 0 | 0 | 1.95 | 2.56 | 51 | 28 | 31 | 0 | 0 | 17.9 |
| | | | | | | | | | | | | | | | | |
| T-937 | 0 - 24 | 2.0 | 6 | 6 | 34 | 30 | 0 | 0 | 3.57 | 3.47 | 79 | 31 | 30 | 0 | 0 | 24.8 |
| T-938 | 24 - 36 | 2.0 | 7 | 7 | 33 | 34 | 0 | 0 | 2.49 | 2.97 | 61 | 30 | 30 | 0 | 0 | 22.3 |
| T-939 | 36 - 54 | 2.0 | 12 | 12 | 23 | 19 | 1 | 1 | 0.47 | 0.63 | 12 | 18 | 17 | 0 | 0 | 15.4 |
| T-940 | 54 - 72 | 2.0 | 10 | 10 | 24 | 16 | 1 | 1 | 0.87 | 0.85 | 19 | 17 | 18 | 1 | 0 | 15.4 |
| T-941 | 72 - 96 | 2.0 | 8 | 8 | 29 | 23 | 1 | 1 | 1.73 | 1.76 | 39 | 23 | 24 | 0 | 0 | 15.5 |
| T-942 | 96 - 120 | 2.0 | 7 | 8 | 32 | 20 | 1 | 1 | 1.97 | 1.51 | 39 | 26 | 27 | 0 | 0 | 15.9 |
| | | | | | | | | | | | | | | | | |
| T-943 | 0 - 10 | 2.0 | 5 | 5 | 37 | 38 | 0 | 0 | 3.52 | 3.09 | 76 | 32 | 29 | 0 | 0 | 19.5 |
| T-944 | 10 - 30 | 2.0 | 6 | 5 | 36 | 34 | 1 | 0 | 2.76 | 2.70 | 61 | 29 | 29 | 0 | 1 | 20.5 |
| T-945 | 30 - 42 | 2.0 | 8 | 7 | 25 | 32 | 1 | 3 | 0.76 | 1.37 | 24 | 26 | 25 | 1 | 1 | 22.9 |
| T-946 | 42 - 60 | 2.0 | 7 | 7 | 31 | 32 | 1 | 0 | 1.63 | 1.98 | 40 | 28 | 28 | 0 | 0 | 20.2 |
| T-947 | 60 - 78 | 2.0 | 7 | 7 | 27 | 28 | 1 | 0 | 1.83 | 1.86 | 41 | 26 | 26 | 1 | 0 | 20.5 |
| T-948 | 78 - 96 | 2.0 | 8 | 8 | 33 | 28 | 1 | 2 | 1.15 | 1.23 | 27 | 23 | 23 | 1 | 1 | 18.4 |
| T-949 | 96 - 120 | 2.0 | 7 | 7 | 37 | 34 | 0 | 0 | 2.86 | 2.74 | 63 | 30 | 30 | 1 | 0 | 14.5 |
| | (ft.) | | | | | | | | | | | | | | | |
| 76-101- 1 | 0 - 13.0 | 2.0 | 6 | 6 | 28 | 28 | 1 | 1 | 1.84 | 2.23 | 46 | 29 | 28 | 1 | 1 | 25.3 |
| 76-101- 3 | 27.3 - 40.8 | 2.0 | 6 | 5 | 36 | 38 | 1 | 0 | 3.36 | 3.39 | 76 | 32 | 33 | 0 | 1 | 20.5 |

White Tail Butte Greenhouse Data.

| Sample No. | Depth (ft.) | Pot Wt. (Kg) | Germination: Days After Seeding for Ten Plants to Emerge | | Germination: Number of Seeds Germinated | | Salt Crust at Germination | Salt Crust at Harvest | Harvest: Plant Dry Weight (gm) | | Harvest: Relative Yield (%) | Harvest: Average Plant Height (cm) | | Black Leaf Tips | Soil Surface Cracks | Field Cap. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | I | II | I | II | | | I | II | | I | II | | | |
| 76-101- 5 | 45.8 - 60.6 | 2.0 | 6 | 6 | 39 | 34 | 1 | 0 | 2.09 | 2.78 | 55 | 26 | 26 | 1 | 1 | 16.8 |
| 76-101- 6 | 60.8 - 135.9 | 2.0 | 6 | 7 | 30 | 34 | 1 | 0 | 2.63 | 2.21 | 54 | 29 | 29 | 0 | 1 | 20.7 |
| 76-101- 7 | 163.8 - 170.1 | 2.0 | 6 | 6 | 32 | 30 | 1 | 0 | 1.92 | 1.32 | 36 | 25 | 25 | 1 | 1 | 20.7 |
| 76-101- 9 | 240.2 - 265.3 | 2.0 | 7 | 8 | 35 | 37 | 1 | 1 | 2.23 | 2.49 | 53 | 29 | 30 | 0 | 1 | 18.4 |
| | | | | | | | | | | | | | | | | |
| 76-102- 2 | 18.0 - 41.0 | 2.0 | 7 | 8 | 27 | 29 | 1 | 2 | 2.12 | 2.05 | 47 | 26 | 27 | 1 | 1 | 21.2 |
| 76-102- 3 | 43.2 - 60.0 | 2.0 | 6 | 6 | 37 | 36 | 1 | 0 | 3.09 | 3.13 | 70 | 33 | 32 | 1 | 0 | 24.5 |
| 76-102- 4 | 60.0 - 68.0 | 2.0 | 6 | 6 | 35 | 36 | 1 | 0 | 2.94 | 2.86 | 65 | 30 | 32 | 1 | 1 | 18.5 |
| 76-102- 5 | 68.9 - 99.0 | 2.0 | 7 | 7 | 24 | 32 | 1 | 0 | 2.43 | 1.88 | 48 | 24 | 25 | 1 | 1 | 21.4 |
| 76-102-11 | 317.8 - 348.2 | 2.0 | 6 | 7 | 29 | 32 | 2 | 1 | 2.45 | 2.08 | 51 | 29 | 29 | 1 | 1 | 19.4 |
| | | | | | | | | | | | | | | | | |
| 76-103- 1 | 0 - 24.5 | 2.0 | 8 | 8 | 25 | 29 | 1 | 1 | 1.09 | 1.50 | 29 | 22 | 23 | 1 | 1 | 18.1 |
| 76-102- 3 | 32.0 - 50.5 | 2.0 | 7 | 7 | 32 | 32 | 1 | 0 | 2.01 | 2.13 | 46 | 27 | 27 | 1 | 1 | 19.2 |
| 76-103- 4 | 91.5 - 109.2 | 2.0 | 5 | 5 | 21 | 32 | 0 | 2 | 3.66 | 4.00 | 86 | 33 | 31 | 1 | 2 | 27.5 |
| 76-103- 5 | 109.2 - 133.0 | 2.0 | 5 | 6 | 31 | 21 | 2 | 2 | 2.67 | 3.22 | 66 | 29 | 28 | 0 | 2 | 28.1 |
| 76-103- 6 | 133.0 - 153.0 | 2.0 | 7 | 7 | 30 | 26 | 2 | 2 | 2.18 | 2.39 | 51 | 27 | 28 | 1 | 1 | 18.9 |
| | | | | | | | | | | | | | | | | |
| 76-104- 1 | 0 - 8.5 | 2.0 | 8 | 7 | 32 | 27 | 1 | 1 | 1.57 | 1.65 | 25 | 27 | 26 | 2 | 1 | 18.0 |
| 76-104- 3 | 15.3 - 23.5 | 2.0 | 7 | 7 | 32 | 31 | 1 | 1 | 1.73 | 1.71 | 39 | 26 | 25 | 1 | 1 | 18.2 |
| 76-104- 4 | 23.5 - 53.5 | 2.0 | 7 | 7 | 40 | 29 | 1 | 0 | 2.08 | 2.11 | 47 | 28 | 29 | 1 | 1 | 19.8 |

White Tail Butte Greenhouse Data.

| Sample No. | Depth (ft.) | Pot Wt. (Kg) | Germination: Days After Seeding for Ten Plants to Emerge | | Germination: Number of Seeds Germinated | | Salt Crust at Germination | Salt Crust at Harvest | Harvest: Plant Dry Weight (gm) | | Harvest: Relative Yield (%) | Harvest: Average Plant Height (cm) | | Black Leaf Tips | Soil Surface Cracks | Field Cap. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | I | II | I | II | | | I | II | | I | II | | | |
| 76-104- 5 | 53.5 - 102.8 | 2.0 | 9 | 10 | 16 | 17 | 0 | 1 | 0.55 | 0.56 | 12 | 16 | 15 | 0 | 1 | 18.1 |
| 76-104- 6 | 102.8 - 153.3 | 2.0 | 6 | 6 | 40 | 31 | 0 | 1 | 3.87 | 4.49 | 94 | 33 | 36 | 0 | 1 | 21.0 |
| 76-104- 7 | 162.7 - 203.3 | 2.0 | 7 | 7 | 32 | 37 | 1 | 0 | 2.61 | 2.62 | 59 | 28 | 27 | 1 | 1 | 15.2 |
| 76-104- 8 | 204.5 - 222.0 | 2.0 | 5 | 6 | 37 | 33 | 1 | 0 | 3.06 | 2.53 | 63 | 31 | 32 | 0 | 1 | 15.3 |
| 76-104- 9 | 222.0 - 234.0 | 2.0 | 7 | 7 | 37 | 37 | 1 | 0 | 4.14 | 3.92 | 90 | 32 | 33 | 1 | 1 | 18.7 |
| 76-104-10 | 245.0 - 255.0 | 2.0 | 6 | 6 | 32 | 35 | 1 | 1 | 3.88 | 4.69 | 96 | 33 | 35 | 1 | 1 | 21.2 |
| 76-104-12 | 263.5 - 274.0 | 2.0 | 7 | 7 | 33 | 32 | 2 | 1 | 3.49 | 3.72 | 81 | 30 | 31 | 1 | 1 | 20.7 |
| 76-104-13 | 274.0 - 283.6 | 2.0 | 5 | 5 | 26 | 31 | 1 | 2 | 3.40 | 3.53 | 78 | 31 | 30 | 0 | 1 | 28.7 |
| 76-104-16 | 343.0 - 356.5 | 2.0 | 7 | 7 | 29 | 18 | 2 | 1 | 2.56 | 2.60 | 58 | 31 | 30 | 0 | 1 | 22.3 |
| | | | | | | | | | | | | | | | | |
| 76-105- 2 | 47.8 - 67.5 | 2.0 | 7 | 7 | 29 | 35 | 2 | 1 | 1.88 | 1.81 | 41 | 25 | 27 | 0 | 1 | 19.7 |
| 76-105- 3 | 98.3 - 113.5 | 2.0 | 6 | 6 | 33 | 32 | 2 | 1 | 3.18 | 3.55 | 75 | 30 | 30 | 0 | 1 | 21.6 |
| 76-105- 4 | 113.5 - 133.5 | 2.0 | 5 | 6 | 32 | 31 | 1 | 0 | 3.39 | 3.33 | 75 | 33 | 33 | 1 | 1 | 16.2 |
| 76-105- 5 | 133.5 - 175.0 | 2.0 | 6 | 5 | 27 | 30 | 2 | 0 | 3.43 | 3.79 | 81 | 23 | 33 | 0 | 1 | 18.5 |
| 76-105- 7 | 204.3 - 229.6 | 2.0 | 6 | 6 | 31 | 34 | 1 | 0 | 4.10 | 4.65 | 98 | 35 | 35 | 0 | 3 | 22.9 |
| 76-105- 8 | 259.0 - 275.0 | 2.0 | 6 | 6 | 32 | 33 | 2 | 1 | 3.61 | 4.07 | 86 | 33 | 34 | 1 | 1 | 21.9 |
| | | | | | | | | | | | | | | | | |
| 76-106- 1 | 0 - 27.0 | 2.0 | 6 | 6 | 36 | 36 | 2 | 1 | 2.68 | 2.60 | 59 | 28 | 29 | 0 | 0 | 26.0 |
| 76-106- 2 | 27.0 - 38.8 | 2.0 | 6 | 6 | 35 | 39 | 1 | 0 | 2.80 | 3.20 | 67 | 31 | 33 | 0 | 1 | 17.5 |
| 76-106- 3 | 38.8 - 84.7 | 2.0 | 6 | 6 | 30 | 23 | 1 | 0 | 1.62 | 1.32 | 33 | 25 | 27 | 1 | 1 | 18.4 |

White Tail Butte Greenhouse Data.

| Sample No. | Depth (ft.) | Pot Wt. (Kg) | Germination: Days After Seeding for Ten Plants to Emerge | | Germination: Number of Seeds Germinated | | Salt Crust at Germination | Salt Crust at Harvest | Harvest: Plant Dry Weight (gm) | | Harvest: Relative Yield (%) | Harvest: Average Plant Height (cm) | | Black Leaf Tips | Soil Surface Cracks | Field Cap. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | I | II | I | II | | | I | II | | I | II | | | |
| 76-106- 4 | 84.7 - 106.8 | 2.0 | 7 | 8 | 34 | 26 | 1 | 1 | 2.08 | 2.34 | 50 | 27 | 29 | 0 | 1 | 22.7 |
| 76-106- 5 | 140.4 - 161.0 | 2.0 | 6 | 5 | 20 | 31 | 2 | 2 | 2.70 | 3.44 | 69 | 30 | 32 | 0 | 1 | 20.5 |
| 76-106- 6 | 161.0 - 169.4 | 2.0 | 6 | 5 | 36 | 35 | 1 | 1 | 4.80 | 4.89 | 109 | 35 | 35 | 0 | 0 | 21.6 |
| 76-106- 7 | 169.4 - 214.0 | 2.0 | 5 | 5 | 21 | 26 | 1 | 1 | 3.43 | 3.44 | 77 | 33 | 31 | 1 | 2 | 20.2 |
| 76-106- 8 | 215.3 - 287.0 | 2.0 | 5 | 5 | 29 | 35 | 0 | 1 | 4.64 | 4.73 | 105 | 33 | 33 | 0 | 1 | 23.8 |
| | | | | | | | | | | | | | | | | |
| 76-107- 1 | 0 - 26.4 | 2.0 | 10 | 13 | 26 | 27 | 1 | 1 | 1.43 | 1.27 | 30 | 22 | 24 | 1 | 1 | 17.9 |
| 76-107- 2 | 27.3 - 73.6 | 2.0 | 7 | 7 | 31 | 32 | 1 | 0 | 1.81 | 1.97 | 42 | 27 | 27 | 0 | 1 | 18.8 |
| 76-107- 4 | 84.1 - 130.3 | 2.0 | 7 | 8 | 40 | 37 | 1 | 0 | 2.07 | 1.55 | 41 | 29 | 26 | 0 | 1 | 18.6 |
| 76-107- 6 | 176.0 - 187.0 | 2.0 | 7 | 7 | 32 | 29 | 1 | 0 | 3.51 | 2.06 | 62 | 32 | 32 | 2 | 2 | 18.8 |
| 76-107- 7 | 187.0 - 215.4 | 2.0 | 5 | 5 | 34 | 33 | 1 | 1 | 4.32 | 4.71 | 101 | 32 | 34 | 0 | 2 | 21.8 |
| 76-107- 8 | 215.9 - 235.0 | 2.9 | 6 | 6 | 34 | 35 | 2 | 1 | 3.84 | 3.81 | 86 | 35 | 34 | 0 | 0 | 30.5 |
| 76-107- 9 | 235.0 - 242.0 | 2.0 | 6 | 6 | 35 | 25 | 1 | 0 | 3.80 | 4.52 | 93 | 32 | 37 | 2 | 1 | 18.5 |
| 76-107-10 | 242.0 - 279.3 | 2.0 | 6 | 6 | 31 | 23 | 1 | 1 | 5.02 | 4.91 | 111 | 31 | 33 | 0 | 1 | 23.1 |
| | | | | | | | | | | | | | | | | |
| STANDARD SOILS | | | | | | | | | | | | | | | | |
| Platner | Surface | 2.0 | 5 | 5 | 33 | 40 | 0 | 0 | 4.36 | 4.55 | 100 | 32 | 32 | 2 | 0 | 15.2 |
| Kimm | Surface | 2.0 | 5 | 5 | 40 | 37 | 0 | 0 | 5.30 | 5.70 | 123 | 32 | 32 | 1 | 0 | 20.6 |
| White Tail Butte Control | Surface | 2.0 | 5 | 5 | 37 | 38 | 0 | 0 | 3.48 | 3.16 | 74 | 30 | 28 | 1 | 0 | 18.8 |

# APPENDIX F

# HYDROLOGY

Records of wells, springs, and test holes

Site number: See text for description of site-numbering system
Perforations: Top and bottom of interval of well open to aquifer given where known. If only bottom is listed, it is the depth of the well or test hole.
Altitude of land surface: Altitudes were estimated from topographic map where an altitude was not reported by owner.
Remarks: CA - Chemical analysis given in table 4.

| Site number | Type of site | Perforations top | Perforations bottom | Water-bearing formation | zone unit | Altitude of land surface (ft) | Depth to water below land surface (ft) | Date of water-level measurement | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 55N 071W 32BC 01 | well | - | 105 | Fort Union | - | 3,680 | - | - | CA |
| 32BD 01 | well | 1,130 | 1,255 | Fort Union | sandstone | 3,648 | flow | - | |
| 33BDA01 | well | 960 | 1,090 | Fort Union | sandstone | 3,700 | flow | - | |
| 072W 03BD 01 | well | 70 | 110 | Fort Union | clinker | 4,100 | 70 | - | |
| 05BC 01 | well | 270 | 360 | Fort Union | sandstone and coal | - | 180 | - | |
| 21CD 01 | well | 90? | 131 | Fort Union | sandstone | 4,200 | 80 | - | |
| 25CA 01 | spring | - | - | Fort Union | clinker | 4,160 | - | - | CA |
| 32CDD01 | well | - | - | Alluvium | - | | 5.2 | 07-31-68 | CA |
| 073W 05AC 01 | well | 92 | 125 | Fort Union | sandstone | 4,110 | 15 | - | |
| 14BC 01 | well | 2,670 | 3,402 | Lance and Fox Hills | sandstone | 4,005 | | | |
| 20CD 01 | well | 78 | 90 | - | sandstone | 4,050 | 55 | - | |
| 26 01 | test | 370 | 380 | Fort Union | coal | 4,195 | 267.5 | 07-13-78 | Cook Coal, CA |
| 074W 10DC 01 | well | 80 | 133 | Wasatch (?) Fort Union | sandstone and coal | 4,080 | 75 | - | |
| 23ABB01 | well | 76 | 92 | Wasatch | sandstone | 4,200 | 68.0 | 08-02-68 | |
| 56N071W 30DBB01 | well | 13 | 23 | Alluvium | sand and gravel | 3,670 | 13.1 | 07-28-78 | CA |
| 30DBB02 | well | 21 | 30 | Alluvium | sand and gravel | 3,670 | 13.8 | 07-28-78 | CA |
| 072W 08AB 01 | well | 140 | 212 | Fort Union | sandstone | | 127.2 | 10-16-68 | |
| 19CDC01 | spring | - | - | Fort Union | slump | 4,080 | - | | CA |
| 21CCC01 | spring | - | - | Fort Union | clinker | 3,950 | - | - | CA |
| 29ACC01 | spring | - | - | Fort Union | coal | 3,950 | - | - | Anderson Coal, CA |
| 30BAB01 | spring | - | - | Fort Union | coal | 4,020 | - | - | Canyon Coal, CA |
| 31DDA01 | test | 663 | 683 | Fort Union | coal | 4,163 | 400.0 | 07-13-78 | Cache Coal, CA |
| 32AC 01 | test | 245 | 260 | Fort Union | coal | 4,238 | 240.6 | 01-08-76 | Canyon Coal, CA |
| 32BAD01 | test | 214 | 252 | Fort Union | coal | 4,226 | 220.5 | 07-13-78 | Anderson Coal |

Table 31

Records of wells, springs, and test holes--Continued

| Site number | Type of site | Perforations top | Perforations bottom | Water-bearing formation | zone unit | Altitude of land surface (ft) | Depth to water below land surface (ft) | Date of water-level measurement | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 56N072W 33BCD01 | test | 324 | 338 | Fort Union | sandstone | 4,204 | 295.2 | 07-13-78 | Sandstone underlying Canyon Coal, CA |
| 34BD 01 | spring | - | - | Fort Union | clinker and coal | 4,000 | - | - | CA |
| 36AB 01 | spring | - | - | Fort Union | - | 3,760 | - | - | CA |
| 073W 21AB 01 | test | 285 | 300 | Fort Union | coal | 4,106 | 180.6 | 10-20-77 | Canyon Coal, CA |
| 25BBA01 | test | 300 | 332 | Fort Union | coal | 4,195 | 213.1 | 06-06-78 | Canyon Coal, CA |
| 25CC 01 | test | 130 | 155 | Fort Union | coal | 4,142 | 107.4 | 07-13-78 | Anderson Coal, CA |
| 25CC 02 | test | 135 | 175 | Fort Union | coal | 4,142 | 88.6 | 07-13-78 | Anderson Coal, CA |
| 25CC 03 | test | 135 | 175 | Fort Union | coal | 4,142 | 88.0 | 07-13-78 | Anderson Coal, CA |
| 25CC 04 | test | 133 | 173 | Fort Union | coal | 4,142 | 78.0 | 07-13-78 | Anderson Coal |
| 27DDC01 | test | 359 | 396 | Fort Union | coal | 4,186 | 213.2 | 01-08-75 | Canyon Coal, CA |
| 29BDB01 | well | 95 | 179 | Fort Union | sandstone and coal | - | 50.4 | 08-01-68 | CA |
| 074W 04CB 01 | well | 2,670 | 3,402 | Lance - Fox Hills | sandstone | 4,092 | - | - | CA |

Salinity analyses of water

[Analytical results in milligrams per liter (mg/L) except as indicated. Analyses by U.S. Geological Survey.]

| Local identifier | Date of sample | Dis-solved silica ($SiO_2$) | Dis-solved calcium (Ca) | Dis-solved magne-sium (Mg) | Dis-solved sodium (Na) | Dis-solved potas-sium (K) | Bicar-bonate ($HCO_3$) | Car-bonate ($CO_3$) | Dis-solved sulfate ($SO_4$) | Dis-solved chlo-ride (Cl) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface water | | | | | | |
| Elk Creek near mouth near Weston | 76-06-15 | 19 | -- | -- | -- | -- | -- | -- | 700 | 5.2 |
| Elk Creek near Recluse | 76-06-15 | 8.2 | -- | -- | -- | -- | -- | -- | 180 | 2.6 |
| Elk Creek tributary near Recluse | 76-06-15 | 10 | -- | -- | -- | -- | -- | -- | 860 | 5.2 |
| Elk Creek near mouth near Weston | 76-06-15 | 20 | 140 | -- | -- | 23 | -- | -- | 550 | 1.8 |
| | 76-10-25 | 4.7 | 200 | 100 | 120 | 27 | 400 | 0 | 290 | 6.8 |
| North Divide Draw near Recluse | 76-06-15 | 4.7 | -- | -- | -- | -- | -- | -- | 540 | 6.1 |
| | 77-04-07 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | Alluvium | | | | | | |
| 55N 072W 32CDD01 | 68-07-31 | 15 | 35 | 40 | 262 | 18 | 679 | 15 | 258 | 13 |
| 56N 071W 30DBB01 | 77-10-19 | 30 | 280 | 120 | 160 | 27 | 370 | 0 | 1,300 | 7.9 |
| 56N 071W 30DBB02 | 76-10-25 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | 76-10-26 | 29 | 250 | 120 | 150 | 29 | 400 | 0 | 1,100 | 7.0 |
| | | | | Fort Union Formation | | | | | | |
| 55N 071W 32BC 01 | 75-08-21 | 9.2 | 8.5 | 6.2 | 140 | 4.2 | 415 | 0 | 16 | 8.8 |
| 55N 072W 25CA 01 | 75-08-21 | 24 | 36 | 12 | 14 | 8.6 | 177 | 0 | 24 | 2.6 |
| 55N 073W 26 01 | 77-10-19 | 8.7 | 49 | 34 | 360 | 12 | 1,290 | 0 | 8.3 | 6.3 |
| 56N 072W 21CCC01 | 76-10-30 | 25 | 68 | 26 | 19 | 14 | 208 | 4 | 140 | 2.5 |
| 56N 072W 29ACC01 | 76-10-30 | 14 | 260 | 130 | 140 | 27 | 106 | 0 | 1,400 | 4.4 |
| 56N 072W 31DDA01 | 76-10-25 | 3.4 | 33 | 19 | 260 | 10 | 542 | 0 | 290 | 7.5 |
| 56N 072W 32AC 01 | 77-10-18 | 6.3 | 61 | 55 | 420 | 12 | 1,220 | 0 | 220 | 26 |
| 56N 072W 33BCD01 | 77-10-18 | 8.0 | 42 | 46 | 390 | 13 | 1,090 | 0 | 200 | 10 |
| 56N 072W 34BD 01 | 75-08-21 | 21 | 76 | 23 | 16 | 16 | 156 | 0 | 210 | 2.8 |
| 56N 072W 36AB 01 | 75-08-21 | 16 | 100 | 43 | 40 | 6.3 | 191 | 0 | 350 | 2.6 |
| 56N 073W 21AB 01 | 77-10-17 | 4.6 | 17 | 9.0 | 320 | 7.6 | 960 | 0 | 23 | 6.6 |
| 56N 073W 25BBA01 | 77-10-18 | 1.7 | 73 | 83 | 480 | 15 | 580 | 0 | 990 | 6.4 |
| 56N 073W 25CC 01 | 77-10-17 | 8.0 | 37 | 27 | 450 | 8.2 | 1,410 | 0 | 48 | 5.0 |
| 56N 073W 25CC 02 | 76-10-26 | 6.3 | 62 | 42 | 520 | 11 | 1,250 | 0 | 480 | 5.4 |
| 56N 073W 25CC 03 | 77-10-12 | 7.8 | 32 | 22 | 390 | 8.3 | 1,160 | 0 | 87 | 6.6 |
| 56N 073W 27DDC01 | 77-10-17 | 7.9 | 31 | 23 | 440 | 9.6 | 1,340 | 0 | 6.9 | 7.0 |
| 56N 073W 29BDB01 | 68-08-01 | 11 | 100 | 62 | 330 | 8.0 | 592 | 0 | 724 | 6.3 |
| | | | | Lance Formation and Fox Hills Sandstone | | | | | | |
| 56N 074W 04CB 01 | 76-08-11 | 17 | 1.3 | .1 | 450 | 2.1 | 1,120 | 240 | 24 | 41 |

Table 37

Salinity analyses of water--Continued

| Local identifier | Date of sample | Dis-solved fluo-ride (F) | Total nitrate plus nitrate (N) | Total ammonia nitro-gen (N) | Total organic nitro-gen (N) | Total ammonia plus organic nitro-gen (N) | Total nitro-gen (N) | Total phos-phorus (P) | Dis-solved boron (B) | Dis-solved solids (sum of consti-tuents) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface water | | | | | | |
| Elk Creek near mouth near Weston | 76-06-15 | 0.6 | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near Recluse | 76-06-15 | .1 | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek tributary near Recluse | 76-06-15 | .4 | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near mouth near Weston | 76-06-15 | .6 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 76-10-25 | .7 | 0.00 | 0.00 | 0.29 | 0.29 | 0.29 | 0.01 | 160 | 947 |
| North Divide Draw near Recluse | 76-06-15 | .4 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 77-04-07 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | Alluvium | | | | | | |
| 55N 072W 32CDD01 | 68-07-31 | .9 | -- | -- | -- | -- | -- | -- | 120 | 992 |
| 56N 071W 30DBB01 | 77-10-19 | .6 | .12 | .10 | 1.0 | 1.1 | 1.2 | 2.5 | 500 | 2,110 |
| 56N 071W 30DBB02 | 76-10-25 | -- | .45 | .04 | 1.3 | 1.3 | 1.7 | .41 | -- | -- |
| | 76-10-26 | .7 | -- | -- | -- | -- | -- | -- | 490 | 1,890 |
| | | | | Fort Union Formation | | | | | | |
| 55N 071W 32BC 01 | 75-08-21 | 1.5 | .03 | .36 | .10 | .46 | .49 | .01 | 80 | 399 |
| 55N 072W 25CA 01 | 75-08-21 | .8 | .36 | .00 | .08 | .08 | .44 | .02 | 160 | 209 |
| 55N 073W 26 01 | 77-10-19 | .7 | .02 | 1.9 | .50 | 2.4 | 2.4 | .08 | 90 | 1,120 |
| 56N 072W 21CCC01 | 76-10-30 | .8 | -- | -- | -- | .22 | -- | -- | 360 | 402 |
| 56N 072W 29ACC01 | 76-10-30 | .6 | .01 | .04 | .50 | .28 | .29 | .02 | 1,000 | 2,030 |
| 56N 072W 31DDA01 | 76-10-25 | .7 | -- | -- | -- | -- | -- | -- | -- | 891 |
| 56N 072W 32AC 01 | 77-10-18 | .7 | .03 | 2.2 | 1.3 | 3.5 | 3.5 | .11 | 80 | 1,400 |
| 56N 072W 33BCD01 | 77-10-18 | .7 | .01 | 1.8 | 2.8 | 4.6 | 4.6 | .24 | 90 | 1,250 |
| 56N 072W 34BD 01 | 75-08-21 | .8 | .60 | .00 | .0 | .08 | .68 | .00 | 530 | 443 |
| 56N 072W 36AB 01 | 75-08-21 | .8 | .03 | .07 | .1 | .19 | .22 | .00 | 410 | 655 |
| 56N 073W 21AB 01 | 77-10-17 | .5 | .01 | 1.4 | .00 | -- | .05 | .44 | 90 | 862 |
| 56N 073W 25BBA01 | 77-10-18 | .2 | .01 | 3.0 | .20 | 3.2 | 3.2 | .06 | 100 | 1,940 |
| 56N 073W 25CC 01 | 77-10-17 | 1.0 | .01 | 1.7 | 1.9 | 3.6 | 3.6 | .36 | 90 | 1,280 |
| 56N 073W 25CC 02 | 76-10-26 | .5 | -- | -- | -- | -- | -- | -- | 80 | 1,740 |
| 56N 073W 25CC 03 | 77-10-12 | .9 | .00 | 1.4 | 30 | 31 | 31 | 6.3 | 80 | 1,130 |
| 56N 073W 27DDC01 | 77-10-17 | .6 | .01 | 1.6 | 6.0 | 7.6 | 7.6 | .99 | 100 | 1,190 |
| 56N 073W 29BDB01 | 68-08-01 | .4 | -- | -- | -- | -- | -- | -- | 80 | 1,540 |
| | | | | Lance Formation and Fox Hills Sandstone | | | | | | |
| 56N 074W 04CB 01 | 76-08-11 | 6.5 | .15 | 1.1 | .00 | .70 | .85 | .02 | 380 | 1,330 |

Salinity analyses of water--Continued

| Local identifier | Date of sample | Hardness (Ca,Mg) | Noncarbonate hardness | Sodium adsorption ratio | pH (units) | Specific conductance (µmho/cm at 25°C) | Temperature (°C) |
|---|---|---|---|---|---|---|---|
| | | | Surface water | | | | |
| Elk Creek near mouth near Weston | 76-06-15 | -- | -- | -- | -- | 1,600 | 11.0 |
| Elk Creek near Recluse | 76-06-15 | -- | -- | -- | -- | 500 | 11.0 |
| Elk Creek tributary near Recluse | 76-06-15 | -- | -- | -- | -- | 1,700 | 12.0 |
| Elk Creek near mouth near Weston | 76-06-15 | -- | -- | -- | -- | 1,500 | 18.0 |
| | 76-10-25 | 910 | 580 | 1.7 | 8.3 | 2,000 | 1.8 |
| North Divide Draw near Recluse | 76-06-15 | -- | -- | -- | -- | 1,050 | 6.0 |
| | 77-04-07 | -- | -- | -- | -- | -- | 11.5 |
| | | | Alluvium | | | | |
| 55N 072W 32CDD01 | 68-07-31 | 252 | 0 | 7.2 | 8.4 | 1,520 | 9.0 |
| 56N 071W 30DBB01 | 77-10-19 | 1,200 | 890 | 2.0 | 7.0 | 2,750 | 10.0 |
| 56N 071W 30DBB02 | 76-10-25 | -- | -- | -- | 6.8 | 3,350 | 9.0 |
| | 76-10-26 | 1,100 | 790 | 2.0 | 6.8 | 2,350 | 9.0 |
| | | | Fort UnionFormation | | | | |
| 55N 071W 32BC 01 | 75-08-21 | 47 | 0 | 8.9 | 8.5 | 432 | 14.2 |
| 55N 072W 25CA 01 | 75-08-21 | 140 | 0 | .5 | 7.7 | 217 | 15.2 |
| 55N 073W 26 01 | 77-10-19 | 260 | 0 | 9.7 | 7.4 | 1,850 | 14.0 |
| 56N 072W 21CCC01 | 76-10-30 | 280 | 100 | .5 | 7.8 | 530 | 9.0 |
| 56N 072W 29ACC01 | 76-10-30 | 1,200 | 1,100 | 1.8 | 7.4 | 2,350 | 6.0 |
| 56N 072W 31DDA01 | 76-10-25 | 160 | 0 | 8.9 | 7.1 | 1,325 | 9.5 |
| 56N 072W 32AC 01 | 77-10-18 | 380 | 0 | 9.4 | 7.5 | 2,300 | 13.0 |
| 56N 072W 33BCD01 | 77-10-18 | 290 | 0 | 9.9 | 7.8 | 2,000 | 13.0 |
| 56N 072W 34BD 01 | 75-08-21 | 280 | 160 | .4 | 8.0 | 439 | 10.0 |
| 56N 072W 36AB 01 | 75-08-21 | 430 | 270 | .8 | 6.5 | 655 | 11.3 |
| 56N 073W 21AB 01 | 77-10-17 | 80 | 0 | 16 | 7.9 | 1,550 | 15.0 |
| 56N 073W 25BBA01 | 77-10-18 | 520 | 48 | 9.1 | 7.6 | 3,100 | 15.0 |
| 56N 073W 25CC 01 | 77-10-17 | 200 | 0 | 14 | 7.2 | 2,050 | 10.5 |
| 56N 073W 25CC 02 | 76-10-26 | 330 | 0 | 13 | 7.6 | 2,210 | 10.0 |
| 56N 073W 25CC 03 | 77-10-12 | 170 | 0 | 13 | 7.8 | 1,900 | 11.0 |
| 56N 073W 27DDC01 | 77-10-17 | 170 | 0 | 15 | 7.5 | 1,950 | 13.0 |
| 56N 073W 29BDB01 | 68-08-01 | 504 | 18 | 6.4 | 8.0 | 2,100 | 11.0 |
| | | | Lance Formation and Fox Hills Sandstone | | | | |
| 56N 074W 04CB 01 | 76-08-11 | 4 | 0 | 102 | 8.4 | 1,750 | 41.5 |

Trace-element analyses of water

[Analytical results in micrograms per liter (μg/L). Analyses by U.S. Geological Survey.]

| Local identifier | Date of sample | Total recoverable aluminum (Al) | Dissolved aluminum (Al) | Total recoverable iron (Fe) | Dissolved iron (Fe) | Total recoverable manganese (Mn) | Dissolved manganese (Mn) | Total arsenic (As) | Total recoverable barium (Ba) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface water | | | | | |
| Elk Creek near mouth near Weston | 76-06-15 | -- | -- | 310 | -- | -- | -- | -- | -- |
| Elk Creek near Recluse | 76-06-15 | -- | -- | 1,700 | -- | -- | -- | -- | -- |
| Elk Creek tribtary near Recluse | 76-06-15 | -- | -- | 730 | 80 | -- | -- | -- | -- |
| Elk Creek near mouth near Weston | 76-10-25 | 70 | 10 | 110 | 20 | 10 | 10 | 1 | -- |
| North Divide draw near Recluse | 76-06-15 | -- | -- | 1,200 | -- | -- | -- | -- | -- |
| | | | | Alluvium | | | | | |
| 56N 071W 30DBB01 | 77-10-19 | 90 | 30 | -- | 120 | 2,600 | 300 | 66 | -- |
| 56N 071W 30DBB02 | 76-10-26 | 47,000 | 10 | 110,000 | 10 | 3,000 | 2,000 | 1 | -- |
| | | | | Fort Union Formation | | | | | |
| 55N 071W 32BC 01 | 75-08-21 | -- | -- | -- | 120 | -- | -- | -- | -- |
| 55N 072W 25CA 01 | 75-08-21 | -- | -- | -- | 50 | -- | -- | -- | -- |
| 55N 073W 26 01 | 77-10-19 | 6,600 | 20 | 37,000 | 20 | 180 | 40 | 10 | -- |
| 56N 072W 21CCC01 | 76-10-30 | -- | -- | -- | 20 | -- | -- | -- | -- |
| 56N 072W 29ACC01 | 76-10-30 | -- | -- | -- | 80 | -- | -- | -- | -- |
| 56N 072W 31DDA01 | 76-10-25 | 90 | -- | 53,000 | 60 | 460 | -- | 9 | 200 |
| 56N 072W 32AC 01 | 77-10-18 | 3,400 | 20 | 190,000 | 320 | 740 | 80 | 2 | -- |
| 56N 072W 33BCD01 | 77-10-18 | 25,000 | 10 | 370,000 | 50 | 2,700 | 70 | 60 | -- |
| 56N 072W 34BD 01 | 75-08-21 | -- | -- | -- | 40 | -- | -- | -- | -- |
| 56N 072W 36AB 01 | 75-08-21 | -- | -- | -- | 1,900 | -- | -- | -- | -- |
| 56N 073W 21AB 01 | 77-10-17 | 47,000 | 20 | 300,000 | 210 | 2,800 | 20 | 140 | -- |
| 56N 073W 25BBA01 | 77-10-18 | 3,800 | 10 | 190,000 | 60 | 940 | 180 | 5 | -- |
| 56N 073W 25CC 01 | 77-10-17 | 12,000 | 60 | 160,000 | 170 | 350 | 50 | 45 | -- |
| 56N 073W 25CC 02 | 76-10-26 | 91,000 | 50 | 250,000 | 40 | 7,800 | 40 | 3 | -- |
| 56N 073W 25CC 03 | 77-10-12 | 140,000 | 140 | 340,000 | 110 | 8,200 | 10 | 290 | -- |
| 56N 073W 27DDC01 | 77-10-17 | 49,000 | 20 | 250,000 | 60 | 1,300 | 50 | 120 | -- |
| | | | | Lance Formation and Fox Hills Sandstone | | | | | |
| 56N 074W 04CB 01 | 76-08-11 | -- | 20 | -- | 40 | -- | 10 | 0 | -- |

Trace-element analyses of water--Continued

| Local identifier | Date of sample | Total recoverable beryllium (Be) | Dissolved beryllium (Be) | Total recoverable cadmium (Cd) | Dissolved cadmium (Cd) | Total recoverable chromium (Cr) | Dissolved chromium (Cr) | Total recoverable cobalt (Co) | Total recoverable copper (Cu) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface water | | | | | |
| Elk Creek near mouth near Weston | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek tributary near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near mouth near Weston | 76-10-25 | 10 | 0 | <10 | 1 | 0 | 0 | -- | <10 |
| North Divide draw near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | Alluvium | | | | | |
| 56N 071W 30DBB01 | 77-10-19 | 0 | 0 | 10 | 1 | 620 | 10 | -- | 190 |
| 56N 071W 30DBB02 | 76-10-26 | 10 | 0 | 10 | 1 | 80 | 0 | -- | 160 |
| | | | | Fort Union Formation | | | | | |
| 55N 071W 32BC 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- |
| 55N 072W 25CA 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- |
| 55N 073W 26 01 | 77-10-19 | 0 | 20 | 10 | 1 | 20 | 0 | -- | 30 |
| 56N 072W 21CCC01 | 76-10-30 | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 29ACC01 | 76-10-30 | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 31DDA01 | 76-10-25 | 0 | -- | <10 | -- | 0 | -- | <50 | 20 |
| 56N 072W 32AC 01 | 77-10-18 | 0 | 20 | 10 | 3 | 40 | 10 | -- | 90 |
| 56N 072W 33BCD01 | 77-10-18 | 0 | 0 | 10 | 2 | 180 | 10 | -- | 350 |
| 56N 072W 34BD 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 36AB 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 073W 21AB 01 | 77-10-17 | 0 | 10 | 10 | 6 | 120 | 10 | -- | 420 |
| 56N 073W 25BBA01 | 77-10-18 | 0 | 0 | <10 | 0 | 30 | 20 | -- | 40 |
| 56N 073W 25CC 01 | 77-10-17 | 10 | 0 | 10 | 9 | 60 | 20 | -- | 80 |
| 56N 073W 25CC 02 | 76-10-26 | 20 | 0 | 20 | 1 | 210 | 0 | -- | 370 |
| 56N 073W 25CC 03 | 77-10-12 | 0 | 20 | 30 | 17 | 270 | 10 | -- | 460 |
| 56N 073W 27DDC01 | 77-10-17 | 10 | 0 | 10 | 7 | 90 | 10 | -- | 230 |
| | | | | Lance Formation and Fox Hills Sandstone | | | | | |
| 56N 074W 04CB 01 | 76-08-11 | -- | 0 | -- | 3 | -- | 0 | -- | -- |

Trace-element analyses of water--Continued

| Local identifier | Date of sample | Dis-solved copper (Cu) | Total recov-erable lead (Pb) | Dis-solved lead (Pb) | Total recov-erable lithium (Li) | Dis-solved lithium (Li) | Total recov-erable mercury (Hg) | Dis-solved mercury (Hg) | Total recov-erable molyb-denum (Mo) | Dis-solved molyb-denum (Mo) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface water | | | | | | |
| Elk Creek near mouth near Weston | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek tributary near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near mouth near Weston | 76-10-25 | 1 | 100 | 6 | 100 | 100 | 0.0 | 0.0 | 0 | 1 |
| North Divide draw near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | Alluvium | | | | | | |
| 56N 071W 30DBB01 | 77-10-19 | 0 | 400 | 3 | 230 | 130 | .4 | .0 | 35 | 8 |
| 56N 071W 30DBB02 | 76-10-26 | 1 | 200 | 1 | 200 | 120 | .1 | .0 | 3 | 4 |
| | | | | Fort Union Formation | | | | | | |
| 55N 071W 32BC 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 55N 072W 25CA 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 55N 073W 26 01 | 77-10-19 | 0 | 100 | 6 | 80 | 70 | .0 | .0 | 7 | 1 |
| 56N 072W 21CCC01 | 76-10-30 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 29ACC01 | 76-10-30 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 31DDA01 | 76-10-25 | -- | 100 | -- | 50 | -- | .0 | -- | 3 | -- |
| 56N 072W 32AC 01 | 77-10-18 | 1 | 200 | 39 | 60 | 50 | .0 | .0 | 6 | 2 |
| 56N 072W 33BCD01 | 77-10-18 | 0 | 200 | 10 | 80 | 60 | 2.1 | .0 | 19 | 5 |
| 56N 072W 34BD 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 36AB 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 56N 073W 21AB 01 | 77-10-17 | 14 | 300 | 72 | 100 | 40 | .6 | .0 | 11 | 4 |
| 56N 073W 25BBA01 | 77-10-18 | 0 | 100 | 3 | 110 | 90 | .0 | .0 | 11 | 3 |
| 56N 073W 25CC 01 | 77-10-17 | 2 | 100 | 92 | 70 | 50 | .0 | .0 | 8 | 0 |
| 56N 073W 25CC 02 | 76-10-26 | 1 | 600 | 2 | 220 | 80 | 1.1 | .0 | 0 | 0 |
| 56N 073W 25CC 03 | 77-10-12 | 2 | 500 | 70 | 230 | 40 | 1.0 | .0 | 7 | 0 |
| 56N 073W 27DDC01 | 77-10-17 | 1 | 300 | 63 | 140 | 50 | .4 | .0 | 11 | 1 |
| | | | | Lance Formation and Fox Hills Sandstone | | | | | | |
| 56N 074W 04CB 01 | 76-08-11 | 1 | -- | 4 | -- | 20 | -- | .2 | -- | 1 |

Trace-element analyses of water--Continued

| Local identifier | Date of sample | Total recoverable nickel (Ni) | Dissolved nickel (Ni) | Total selenium (Se) | Dissolved selenium (Se) | Dissolved vanadium (V) | Total recoverable zinc (Zn) | Dissolved zinc (Zn) |
|---|---|---|---|---|---|---|---|---|
| | | | | Surface water | | | | |
| Elk Creek near mouth near Weston | 76-06-15 | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek tributary near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- |
| Elk Creek near mouth near Weston | 76-10-25 | <50 | 2 | 0 | 0 | 0.1 | 20 | 20 |
| North Divide Draw near Recluse | 76-06-15 | -- | -- | -- | -- | -- | -- | -- |
| | | | | Alluvium | | | | |
| 56N 071W 30DBB01 | 77-10-19 | 150 | 2 | 6 | 0 | 2.0 | 430 | 10 |
| 56N 071W 30DBB02 | 76-10-26 | 100 | 4 | 7 | 1 | .0 | 590 | 230 |
| | | | | Fort Union Formation | | | | |
| 55N 071W 32BC 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- |
| 55N 072W 25CA 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- |
| 55N 073W 26 01 | 77-10-19 | <50 | 10 | 0 | 0 | 1.3 | 100 | 0 |
| 56N 072W 21CCC01 | 76-10-30 | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 29ACC01 | 76-10-30 | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 31DDA01 | 76-10-25 | <50 | -- | 0 | -- | -- | 10,000 | -- |
| 56N 072W 32AC 01 | 77-10-18 | 50 | 8 | 0 | 0 | .0 | 140 | 10 |
| 56N 072W 33BCD01 | 77-10-18 | 150 | 5 | 2 | 0 | .0 | 400 | 0 |
| 56N 072W 34BD 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- |
| 56N 072W 36AB 01 | 75-08-21 | -- | -- | -- | -- | -- | -- | -- |
| 56N 073W 21AB 01 | 77-10-17 | 300 | 5 | 4 | 0 | 1.9 | 800 | 0 |
| 56N 073W 25BBA01 | 77-10-18 | 50 | 1 | 0 | 0 | .0 | 110 | 10 |
| 56N 073W 25CC 01 | 77-10-17 | 50 | 2 | 2 | 0 | .3 | 220 | 10 |
| 56N 073W 25CC 02 | 76-10-26 | 150 | 2 | 2 | 0 | 1.8 | 3,100 | 170 |
| 56N 073W 25CC 03 | 77-10-12 | 150 | 0 | 8 | 0 | 3.1 | 2,100 | 10 |
| 56N 073W 27DDC01 | 77-10-17 | 150 | 1 | 5 | 0 | .7 | 1,900 | 10 |
| | | | | Lance Formation and Fox Hills Sandstone | | | | |
| 56N 074W 04CB 01 | 76-08-11 | -- | 0 | 0 | 0 | .0 | -- | 10 |

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